ELEMENTS

OF

NATURAL PHILOSOPHY

DELINEATED.

BY

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NATURAL PHILOSOPHY.

VOL. II.

The Doctrine of fixed or ſolid Bodies.

§. 328. THE ſpace through which all fluid and ſolid bodies are diſtributed, is called the *heavens*. The ſolid bodies floating therein, none of which touches the other, are called ſtars or *mundane* and *celeſtial bodies*, and conſiſt of fixed and of fluid matters. The conſtituent parts of the fluid matters, which are never changed into others, as of the air, water, fire and light, are therefore in like manner to be deemed fixed bodies, as they ever continue what they are. But the nature of theſe conſtituent parts has not hitherto been diſcovered. So

that in the doctrine of fixed or solid bodies we have barely to explain the properties of the heavenly bodies together with their fixed and fluid parts. As the last have been already considered in their essence, by which they are distinguished from each other; so in the present undertaking we have only to consider what agrees to them, in so far as they constitute parts of the heavenly bodies, and stand in a certain connection with the fixed parts thereof.

PART I.

Of the EARTH.

SECT. I.

Of the EARTH as a mundane body.

CHAP. I.

Of the FIGURE of the EARTH.

§. 329. THE earth is round, and floats freely in the heavens, or is out of contact with any other heavenly body. The last is at first sight clear from this, that sun and moon together with the other stars appear to rise and to set. For suppose this appearance to arise either from the stars actually moving about the earth, or from the earth

turning on itſelf, there muſt be always a free ſpace between her and the ſtars. And ſecondly, this is confirmed from the earth having been ſeveral times ſailed round. *Magellanes* the *Portugueſe* firſt performed this voyage in the year 1519, and finiſhed it in 1124 days: and *William Cornelius Schouten* undertook it in the year 1615, and compleated it in 749 days. The roundneſs of the earth appears hence at ſea, that the maſts of diſtant ſhips are ſeen before they themſelves come in ſight. Had the ſea no convexity, but either an excavated figure, or an even ſurface, on which right lines only could be drawn; ſhips indeed would appear at a diſtance leſs, but yet preſent themſelves full to the eye from the top of the maſt down to the part where they are in water. In like manner, in a clear ſky the ſun would be ſeen at the eaſtern horizon at the very ſame time by the weſtern, that it would by the eaſtern inhabitants, were the earth level.

§. 330. The connection of the fixed and fluid parts of the earth ſubſiſts by the gravity, with which they are impelled towards each other, and to a common point in her centre. But the gravity of a body at a leſs diſtance from this centre is greater than at a greater. For, on a high mountain a pendulum goes ſlower, than at its foot (§. 46.) The experience by which M. *de la Condamine* found this in 1743 in Peru, he deſcribes in his *Voyage de la Riviere des Amazones*, p. 180. & ſeq. On the banks of the *Amazon* at *Para*, the pendulum performed in 24

hours 98770 vibrations; in *Quito* 98740, and on the mountain *Pichincha* 98720. And thus in *Quito* there was 30, and on the *Pichinchia* 50 vibrations leſs in 24 hours than in *Para*. *Quito* lies been 14 and 1500 toiſes or *French* rods higher above the ſea than *Para*; and the mountain *Pichincha* 750 toiſes higher than *Quito*.

§. 331. The intenſity of gravity decreaſes, as the ſquare of the diſtance from the centre, to which it is directed, increaſes. Or, the intenſity of gravity in a leſs diſtance from the centre, to the intenſity of gravity at a greater diſtance from it, is inverſely as the ſquare of the greater diſtance to the ſquare of the leſs. If, for inſtance, the leſs is = 1, and the greater = 2; the gravity in the leſs is to that in the greater, as 4 to 1. Now be the point to which the body is impelled by gravity, the centre of the earth, or any other centre; the action of gravity always happens in converging lines, which at laſt meet in the centre. If therefore a ſurface is of a circular form, the lines A D, B D and C D, fig 16. plate 11. along which the gravity, acting on the baſe A C B, propagates its effect, form a cone, whoſe vertex is in the centre of a body, for inſtance, the earth. On cutting the cone in E F parallel with A B, the circular ſurface E G H is to the circular ſurface A C B, as the ſquare of the diameter E F, to that of the diameter A B. So much gravity as acts on the ſurface A C B, ſo much alſo acts on the ſurface E F G. But the parts of the gravity on the ſurface

ſurface E F G are by ſo much nearer together, as the ſurface A C B is bigger. And thus the denſity, and conſequently the intenſity of the gravity on E G F, to the denſity and intenſeneſs of the gravity on A C B, is inverſely as the ſquare of the diameter A B to that of the diameter E F. Now A B is to E F, as C D to G D. So that the intenſeneſs of the gravity on E G F to that of the gravity on A C B, is inverſely as the ſquare of the greater diſtance C D to that of the leſs G D.

§. 332. Were therefore a body, whoſe baſe was E G F, conveyed from G to C; its gravity in C would be to the gravity it had in G, inverſely as the ſquare of the leſs diſtance G D to that of the greater C D. And thus if C D = 2, and G D = 1; the gravity in A C B is to that in E G F, as 1 to 4.

§. 333. The fall of a heavy body in the firſt ſecond of time, ariſes from the gravity acting on it. The intenſer therefore it acts on it in the firſt ſecond, the farther it falls in that ſecond. And thus the ſpace, which a falling body at a great diſtance from the centre of the earth accompliſhes in the firſt ſecond, is to the ſpace, through which it falls from a leſs diſtance in the firſt ſecond, inverſely as the ſquare of the leſs diſtance to that of the greater: as 1 to 4, for inſtance, when the leſs diſtance = 1, and the greater = 2.

§. 334. For a body therefore, which begins to fall from a double diſtance from the earth's centre, to

finiſh ſo great a ſpace, as it would finiſh in a certain time; for inſtance a ſecond, ſo it began to fall from a ſingle diſtance from the ſaid centre; it muſt have a double time. For, the time, which a falling body takes up in a certain ſpace, is equal to the ſquare root of this ſpace (§. 35). The double time is to the ſingle, as the double diſtance to the ſingle diſtance. Fall therefore a body, which begins to fall from a greater diſtance from the earth's centre, through ſo great a ſpace, as it would fall, ſo it began to fall from a leſs diſtance; the time, which it takes up in its fall from the greater diſtance through the ſaid ſpace, is to the time, in which it would accompliſh this ſpace from a leſs diſtance, as the greater is to the leſs diſtance.

§. 335. Were the earth a perfect ſphere and at reſt, a body on its ſurface would every where have the ſame gravity. For, if perfectly round, all the points on its ſurface would be equidiſtant from its centre. So that gravity acting on one and the ſame body, would in regard to its diſtance from the centre decreaſe no where on the ſurface of the earth. The gravity, by which bodies are impelled to the centre of a ſphere, is nothing other but the centripetal force (§. 91). And had thus the earth no circular motion, the gravity alſo of bodies in and upon it would be weakened by no counter-acting force (§. 94).

§. 336. But a body, neither decreaſed nor increaſed in maſs, is lighter at the equator or line, than at the poles. For, a pendulum moves ſlower at the equator,

equator, and quicker at the poles, than at *Paris*, without any neceſſity of aſcribing this difference either to alteration of its maſs or its length (§. 46).

M. *Richer* obſerved this firſt in 1672 on the iſland of *Cayenne*, diſtant 4 degrees 55 minutes from the equator northwards. For, as in *Auguſt* he obſerved the paſſage of the fixt ſtars through the meridian, he perceived his pendulum clock went daily 2 minutes 28 ſeconds too ſlow. He therefore ſhortened the pendulum till the clock went juſt. On his return to *France*, he compared the length of his pendulum, and found it about 1 ¼ line ſhorter. In like manner, after *Richer*, *Varin* and *Des Hayes* in 1682 on the iſlands *Gorea*, *Guardaloupe*, and *Martinico*, and *Couplet* in 1697 in *Paraiba*, whither they went from *Paris*, found themſelves obliged to ſhorten their pendulums, to have their clocks go juſt with the ſtars. We are not to aſcribe the length, which they were obliged to take from their pendulums, to the heat of the ſun at the line (§. 127). Indeed, according to *Picart*'s remark, an iron wire, which in the cold of winter is a foot long, is at the fire ¼ line longer; and according to *De la Hire*'s obſervation a ſix-foot iron wire is lengthened at the heat of the ſun about ⅔ line. But the length, which was to be taken from pendulums, came to a good deal more. The hiſtory of theſe obſervatioos *Newton* gives in his *Principia*, book 3. propoſ. 20. And thus it hence appears, that pendulums move ſlower at the line than at *Paris*.

The mathematicians, who in 1736 and 1737 meaſured in *Lapland* a degree, that interſects the polar circle, built on the banks of the river *Tornea* at *Pello*, in the latitude of 66° 48′ a proper room for their inſtruments, and kept it heated to that pitch that for 5 days ſucceſſively, in which in 1737 they obſerved the paſſage of *Regulus* acroſs the meridian, the thermometers indicated one and the ſame degree of heat. The year after, they obſerved at *Paris* the tranſit of *Sirius* over the meridian. The pendulum-clock, which they uſed for the purpoſe, ſtood in a place, whoſe heat was equal to that of the room at *Pello*. From comparing obſervations they found at laſt, that the pendulum at *Pello* went daily, that is, from one tranſit of a ſtar through the meridian to the following, about 59 ſeconds quicker than at *Paris*. The latitude of *Paris*, or its diſtance from the equator, is 48° 50′. The pains that were taken in theſe enquiries *Maupertuis* deſcribes in his *Figure de la terre*.

How the *French* mathematicians, ſent to the equator in 1737, had found that in *Peru* pendulums ſwing ſlower than at *Paris*, *Bouguer* relates in his *Figure de la terre*.

§. 337. The gravity may be weaker at the equator than at the poles from a twofold cauſe: either from the earth being raiſed at the equator, and flat or depreſſed at the poles (§. 330); or from its motion about its axis (§. 96). So that the query is, to which of both theſe cauſes we are to aſcribe the diminution

minution of gravity at the equator? Should the fixed or ſolid parts of the earth under the equator not be elevated, and thus not more diſtant from the centre than the ſolid parts under the poles; the ſea under and at the equator would not remain within its ſhores. For, as the gravity is leſs under the equator than towards the poles; the decreaſe of the gravity, in defect of the ſaid circumſtance, would ariſe from the revolution of the earth. And thus the water would not only have a centrifugal force, or a conatus to remove from the centre, and conſequently from the bottom of the ſea, but alſo actually remove, on account of its weak coheſion with the bottom.

§. 338. But the ſhores under the equator are higher than the ſea. Conſequently the fixed parts of the earth under the equator A B, fig. 2. plate XIII. are more diſtant from the centre C, than under the poles N and S. So that the earth is an oblate ſpheroid, raiſed under the equator A C B, and flat or depreſſed under the poles. Its diameter, or the right line, which may be drawn through the equator and the centre, is greater than its axis N C S, or the right line, which may be drawn through both the poles and the centre.

This figure *Newton* in his *Principia*, book 3. propoſ. 19. and *Huygens* in his diſſertation *De cauſa gravitatis*, have aſcribed to the earth, on conſidering the decreaſe of the gravity under the equator and the circular motion of the earth. Whereas in *France* they

would

would maintain the contrary, and consequently they deem the earth's axis greater than the earth's diameter, bottoming on what the two *Cassini* pretended to have found by geometrical mensurations. For, according to these, the degrees of the meridian should grow still less, the nigher we approach the north pole. And were even this admitted, we could not reject the said opinion of the *French*. For, were the earth's axis A *a* fig. 11. plate II. greater than its diameter B *b*, and consequently the earth at the poles A and *a* tapering, and under the equator B and *b* pressed flat; the rounding at the poles A and *a* were to be considered as an arch of a less circle; and the rounding at the equator B and *b*, as an arch of a greater circle. But a degree of a less circle is less than a degree of a greater. Yet as the decrease of the gravity, which was observed last century by means of pendulums under the equator, did not agree with the mensurations of the *Cassini*; the academy of sciences of *Paris* wanted to be at a greater degree of certainty in this matter. And at the command of the prince now reigning, through the representations of cardinal *Fleury* and count *Maurepas*, in 1735 two learned companies were sent, one to measure a degree of the meridian at the north polar circle; and the other, the first degree of the meridian at the equator in *America*. In the first were Mess. *Maupertuis*, *Clairaut*, *Camus* and *le Monnier*: in the second, Mess. *Godin*, *de la Condamine* and *Bouguer*. The reason, why it was resolved to measure two degrees of the

the meridian ſo diſtant aſunder, is eaſy to imagine. If the difference between two near degrees is ſmall, it may be deemed an error in the menſuration. But if the degrees are very diſtant aſunder, their difference can be conſidered as no ſuch error. For, if multiplied by the number of intermediate degrees; it is eaſy to ſee, that it did not ariſe from a bare error in menſuration, come a very conſiderable quantity out. The academicians ſent to the north, found that a degree of the meridian, interſecting the polar circle, meaſured 57437 toiſes. A degree of the meridian in *France*, northwards from *Amiens* to *Malvoiſine*, according to *Picart*'s determination, contained 57060 toiſes only. So that a degree of the meridian in *France* is 377 toiſes leſs than the ſaid degree of the meridian at the north polar circle. In *America* the academicians found, that the firſt degree of the meridian meaſured 56553 toiſes. And thus 307 toiſes leſs than in *France*. From this it appears, that the degrees of the meridian increaſe from the equator to the north pole. So that the diameter of the earth A *a* is greater than its axis B *b*, and conſequently the earth under the equator raiſed, and depreſſed under the poles. For, if the earth is flat under the poles *b* and B, fig. 11. plate 11. the rounding there is to be conſidered as an arch of a greater circle; and the rounding under the equator A and *a* as an arch of a leſs. But a degree of a greater circle is greater than a degree of a leſs.

§. 339

§. 339. According to the table, in which *Maupertuis* at the end of his *Elemens de geographie* exhibits the degrees of longitude and latitude by calculation, the diameter of the earth contains 6562480 toifes; and its axis, 6525600. The firft number is to the fecond, as 178 to 177 nearly. And thus the earth's axis is 36880 toifes lefs than its diameter. *Bouguer* in his *Figure de la terre*, p. 298. in the table calculated for the degrees of latitude gives to the earth's diameter 6562391 toifes; and to its axis, 6532903; and thus makes the laft only about 29488 toifes lefs than the diameter. The firft number is to the laft as 179 to 178 nearly. According to *Newton*'s calculation, the earth's diameter is to its axis, as 230 to 229; and according to *Huygens*, as 578 to 577.

§. 340. As the figure of the earth is elliptical (§. 338), the lines, in which heavy bodies fall on the furface, go not all of them to one and the fame centre, or to the earth's centre. For, the elliptical line may be confidered as a line, confifting of different circular arches, if you fix on certain points, as centres in the greater and lefs axis of the ellipfis. Now fall a body on this elliptical furface to what point foever of thefe circular arches; it falls on the line, which goes to the centre of the arch. But as the centre of one circular arch differs from that of another; fo the line of direction of a falling body goes to a different centre, when falling towards one arch, from what it does, when falling towards another.

§. 341. But as the difference of the quantity, by which the earth's diameter exceeds the axis (§. 339), in comparifon with the large body of the earth, is fomething inconfiderable; we may without committing any very great error, abide by the common and received manner of fpeaking; viz. that the bodies above, on, and in the earth feek to fall towards its centre.

CHAP. II.

Of the diurnal MOTION of the EARTH.

§. 342. IN order to affign a reafon, wherefore bodies partly continually grow lighter, the nearer they come to the equator; partly earth and water among themfelves have attained the height, which has been found out by geometrical menfurations (§. 336, 338); the motion of the earth about its axis is the only one, by which both may be intelligibly explained. Yet we are here to premife, that the matter, which now conftitutes the firm part, or land, was once fluid, or at leaft foft. For, though by the earth's circular motion not only the matters of the equator, but alfo of the circles, lying parallel therewith, are diminifhed in their gravity; yet at the equator this diminution is greater than in any parallel circle. The reafon is thus: the equator and the parallel circles perform their revolutions in equal times. And therefore the revolution of the equator is fo much the quicker, the greater is its circumference than that of the parallel circles

circles (§. 27). But the quicker the circular motion, the intenſer is the centrifugal force, and the weaker the centripetal (§. 95), and conſequently the gravity (§. 17, 91). If it be aſked, how it has happened, that the matter, which became gradually firm, has by the circular motion removed farther than the water from the centre? the anſwer is, becauſe it is denſer than the water. So that, for inſtance, a cubick foot of ſuch matter had more weight than a cubick foot of water. Now if two unequally heavy bodies with equal velocities move about a point; the heavier acquires a greater centrifugal force, than the lighter (§. 97).

§. 343. We may therefore with good grounds maintain, that the earth turns about its axis, which is what conſtitutes its diurnal motion.

SECT. II.

Of the viſible and conſtituent PARTS of the EARTH.

CHAP. II.

Of the ſeveral SPECIES of thoſe PARTS.

§. 344. THE ball of the earth conſiſts of water and of every ſpecies of firm matter whoſe connection we in general call the earth.

§. 345

§. 345. The ſpecies of theſe firm matters are metals, ſtones, ſalts, ſulphur, and earth in particular: we call ſulphur every thing that melts in the fire, and may be reſolved into flame with a ſtrong-ſmelling fume. Salts melt in the fire, and diſſolve in water. Metals may be ſmelted by the force of fire, and ſtretched by the hammer, and drawn to wire. Take, for inſtance, a cylinder of ſilver, weighing 45 marks, or half pounds, 22 inches long, and 15 lines in diameter, and gild it over with leaf-gold, prepared by the gold-beaters: for gilding theſe 45 marks, each of which holds 8 ounces, we never take above 6 ounces of gold, many times only 2, and oftener not much above 1 ounce. This lay of gold, which encompaſſes the lump of ſilver, is never thicker than the 15th part of a line; nay often the 30th only, or 45th, or even the 90th. You lengthen the cylinder, till only, or even not once, ſo thick, as a hair, ſo you draw it thro' different holes one after the other, and one ever leſs than the other. The gold, which covers this piece of ſilver, ceaſes not to gild it ſtill, drawn to never ſo aſtoniſhing a length. *Reaumur* weighed carefully half a dram of the fineſt thread or wire, and as carefully meaſured its length, and found it 202 feet. An ounce contains 16 half drams. And thus an ounce was 3232 feet long, and conſequently a mark, 25856. Now the entire cylinder weighed 45 marks. So that it was drawn out by the wire-drawer to a length of 1163520 feet. Now 22824 feet make a *German* mile. And thus the

the cylinder was changed to a thread 50 *German* miles in length. Such a thread is flatted between extraordinarily smooth wheels or rollers of steel, when it is lengthened still about $\frac{1}{7}$: and thus to a length of 57 miles. *Reaumur* shews in the memoires of the academy in the experiments and reflections for the year 1713, the astonishing ductility of several matters; as that the thickness of the gold, which lies on the said thread, amounts not to $\frac{1}{175000}$ of a line, even though 2 ounces were used for the gilding. To the characters, by which metals are distinguished from each other, belongs in particular their specifick gravity. By the hydrostatical experiments (§. 71), the specifick gravity of gold, lead, silver, copper, iron and tin to that of airless water, is as 19636, 11345, 10535, or 11087, 8843, 7852, 7321, to 1000. Stones, on account of their hardness and fragility, admit neither drawing, nor stretching by the hammer. Earth in particular, as the matter, which is distinct from all the firm matters hitherto described, has the following characters. It may be penetrated by water, and thereby expanded into a greater space; and it consists of such flexible parts as to admit kneading and drawing, and hence it assumes all forms, that one inclines to give it. These properties *Reaumur* discovered by a variety of trials. His dissertation on the nature of earth is in the memoires for the year 1730. He caused to grind grains of sand so fine, as earth-dust could never possibly be more so, and moistened this sand-dust

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with water; but could never make a dough or paſte of it, that would admit kneading, like a dough of earth. This earth is more conſtant in the fire than gold. *Homberg* by *Tſchirnhauſen*'s burning-glaſs turned it to glaſs, in weight a tenth part only of the weight of gold. Gold conſiſts of mercury, metallick ſulphur and earth. In the focus of a burning-glaſs gold fumes at firſt. This happens, ſo the mercury ſeparates from the metallick ſulphur by the heat. The earth remains behind. With it the metallick ſulphur melts, and then it appears in the form of glaſs; which held a long time in the focus, goes on to fume and the ſulphur evaporates, and the glaſs turns to an earth, that may be rubbed, but not melted any more. The experiments are in the memoires for the year 1702.

CHAP. II.

Of the FIRE in the EARTH.

§. 346. IN the bowels of the earth is contained a conſtant ſtore of fire. For the firſt proof of which, *Mairan*, in his *Diſſertation on ice*, P. I. c. II. aſſumes the ſenſation of heat in deep pits, which continues unchanged, though the heat of the air at the earth's ſurface does not. In the pits of the obſervatory at *Paris*, which yet, reckoning from the firſt floor, are only 84 feet deep, there is obſerved in the thermometer the whole year round neither a remarkable riſing nor falling. In the mines, this degree

 of

of heat remains from ſuch a depth to one of between four and ſix hundred feet regularly one and the ſame. After this, it increaſes with the depth, and is ſometimes ſo intenſe, that the mine-people could not hold out and live therein, were they not ſupplied with ſome cooling and freſh air, either by air-ſhafts, or water-falls. *Boyle* confirms this by remarkable experiences in his treatiſe *De temperie ſubterranearum regionum.* For a ſecond proof M. *Mairan*, c. 12. uſes the conſtant fluidity of the water at the bottom of the ſea. For, that it freezes not thereon, can by no means be aſcribed to the action of the ſun's rays, his force not reaching above 12 feet deep into the earth; as ice-pits ſhew, in which ice keeps at this depth. And thus ſuppoſing water were 10, or 15, nay 20 times more porous than earth; the heat of the ſun could act at 120, or 180, and at moſt 240 feet deep through the water of the ſea. At a greater depth it muſt therefore have turned to ice. But depths of two, three and four hundred fathoms contradict this. Laſtly, M. *Mairan* appeals to the fire burſting out of the ſea. As out of it rocks and iſlands, all in ſmoke and flame, have at times emerged. An inſtance to this purpoſe we had in the year 1707, of an iſland comming forth out of the *Archipelago*. Of which an hiſtorical account may be read in M. *Morus*'s *New enquiry into the changes of the earth*, P. 2. c. 2. An inſtance as extraordinary we find in the *General hiſtory of nature*, T. 1. P. 2. art. 17. p. 282.

§. 347.

§. 347. Fire arises in the earth, when the matters, in which it is contained, are resolved into parts, differing in nature. Among these are sulphur, iron and calcined stone, and shells of snails, oysters, &c. Calcined matters are heated, when moistened and penetrated by water. In like manner, iron and sulphur give a great degree of heat, when mixed together, and worked up with water. The experiment, by which *Lemery* discovered this effect, is described in the memoires of the academy for the year 1700.

§. 348. If the fire in a place under the earth acquires, by the quantity of the inflammable matters, a degree of force, whereby the elasticity of the air, confined in the contiguous cavities, is heightened; it either bursts through at a place on the surface of the earth, and violently throws up molten and unmolten matters promiscuously: or causes an earthquake, whereby certain parts of the earth's surface are shaken and forced upwards. The bursting out of the fire may be so violent, that great weights of earth and stone may be made to rise up, whereby mountains and rocks are formed. An example to this purpose is the island mentioned (§. 346.) which arose out of the bottom of the *Archipelago* in 1707, and continued to increase till 1711. Not only a thick smoke, which covered the island *Santorin*, arose, but bright fire burst out, and burnt and glowing stones were thrown into the air with a violent noise quite out of sight, falling again into the sea at the distance of some miles off. If the fire, arisen in and

under a mountain, has a conſtant ſupply of new fuel; as partly, a quantity of the matters thrown out falling back again into the opening; partly, certain pieces of the mountain tumbling in; partly, the bowels of the mountain containing a ſufficient ſtock of inflammable matters, the mountain continues conſtantly burning withinſide; which ſometimes rages to a degree as to belch out fire, when the burning gets the upper hand. We have a ſhort hiſtory of vulcanos and of the moſt remarkable earthquakes in the *General hiſtory of nature*, T. 1. P. 1. art. 16. Fire only breaks forth, when at the ſides of the place, where it is generated, it finds no cavities, in which it may ſpread and diffuſe itſelf along with the air heightened in elaſticity, and gains to ſuch a degree of violence, as the weight and firmneſs of earth, with which it is covered, cannot reſiſt. Whereas if the air, heated by the fire, breaks forth into the contiguous cavities and veins, but cloſe, or without vent, and by a ſhock compreſſes the air contained in them; this air ſeeks a vent, and hereby ſhakes the parts of the earth, that cover this vein, or makes them fly into the air, ſo the elaſticity of the air be ſufficiently intenſe.

§. 349. The force of the fire under the earth and in vulcanos ariſes from the following cauſes. Firſt, it is ever more violent, the more matters come gradually to be heated. The fiery ſtream, or *lava*, which in 1751 and 1752 ran out of *Veſuvius* for three months together, conſiſted of many millions

of

of quintals of molten matters; as may appear by calculation, ſo we aſſume in general for the length of the ſtream 6000 paces only, and for the breadth 30, and depth 1. What degree of heat does not a ſingle quintal of melted metal caſt! How much more therefore, when ſo many millions of quintals are melted together! Secondly, the heat of melting and mutually burning matters is in theſe cavities of the earth heightened hereby, viz. that they are conſumed in a ſpace, in which they can little ſpread and diffuſe themſelves. Add to this, thirdly, the weight of the upper earth incumbent and preſſing on the under; ſo that again the fire of the under is reſtrained from ſpreading, Fourthly, the violence of the fire increaſes by the preſſure, with which the confined air acts againſt it by its uncommonly heightened elaſticity. By the draught of air through the top of a vulcano, the action of the internal is heightened rather than weakened; as thereby coming into motion, whereby the fire is the more excited, as wind-furnaces confirm.

§. 350. That ſand, ſtones and other matters are thrown out of vulcanos; and in earthquakes the firmeſt parts of the earth are burſt aſunder, is accounted for from the violence of the elaſtick matters, that are confined in the cavities of the earth, and expanded by the power of fire. Among theſe matters are air, and ſeveral kinds of damps or vapours. The air there is partly that, which fills up the empty ſpaces of other viſible matters; partly

 that,

that, which in certain matters, as the nitrous, is confined and compreſſed. By experiments that were made, it has been found, that an ounce of gunpowder blows up 90 pounds of looſe earth, and 120 of ſtone wall. We further know from experience, that the ſtouteſt bladders do burſt by the elaſtick force of the air, with which they are filled, when the air contained in them is heated over glowing coals, at ſuch a diſtance as not to burn the bladders. We will only ſay, a cubick foot of included air can by its elaſticity, when expanded by heat, raiſe a quintal weight. How many thouſand cubick feet of air may be contained in a large cavity, where a ſubterraneous fire is kindled? How many thouſand quintals of matter may not thus be raiſed thereby? But the ſpring of a cubick foot of confined air may be heightened much more by the heat than we at firſt aſſumed. The damps or vapours in the cavities of the earth are in like manner two-fold. Some conſiſt of water; ſome of other matters, as the nitrous. The elaſtick force in the laſt is well known. But the firſt alſo becomes elaſtick by heat, and thereby acquires a far greater force than gunpowder (§. 136. n. 2.) Laſtly, melted metals fly about with great violence, when water flows in upon them.

CHAP.

CHAP III.

Of the REMARKABLES of MOUNTAINS.

§. 351. ON the mountains it is colder than in the valleys. On the *Alps* and *Pyrenees* the ice has not been ſeen to melt from time immemorial. M. *Altman* publiſhed in 1751, an hiſtorical and phyſical deſcription of the ice-mountains of *Switzerland.* In *America* in the torrid *Zone*, an everlaſting ſnow lies on the high range of mountains, notwithſtanding the fire to be met with in their wombs, and at times burſting forth with great rage; as appears from the relation of M. *Bouguer*, inſerted into the memoires of the academy for 1744.

§. 352. From this it appears, that the rays of the ſun, at the diſtance from the centre of the earth, at which the ſnow remains lying in the midſt of ſummer on ranges of mountains, are ſhort of the force of melting the ſnow; and conſequently another cauſe beſides muſt concur, for a degree of heat to ariſe there, by which the ſnow may diſſolve. The effect of the ſubterraneous fire is reſtrained by the firmneſs and denſity of the matters in mountains, as to be unable to reach the height at which the ſnow lies, except when the fire arrives to an extraordinary degree of force. Again, the air on high mountains is not ſo rich in fire-holding matters as the air in valleys. So that in the air on mountains there is not

ſo great a quantity put into motion by the rays of the ſun, as in the air over the lower ſurface of the earth.

§. 353. Were therefore the whole ſurface of the earth ſo firm, denſe and raiſed, as are the mountains; perpetual cold would prevail every where upon it, ſuch as we now find on mountains. A degree of cold juſt ſo great would be continually found in *Germany*, *France* and *Italy*, at the height of the air, equal to that of mountains, did not the warm vapours, which riſe out of the earth, reach to the ſaid height of the air.

§. 354. That thus the water to be found in the air is at times froze in the hotteſt days, and ſnow and hail produced out of it, is owing either to the defect of warm vapours from the earth, or to the acceſſion of frigorifick matters, that are driven thither by the wind from cold quarters.

§. 355. And thus we cannot hitherto ſay, how near we muſt be to the ſun, in order to be ſenſible of ſo great a heat only from his rays, as is that, in which ſnow cannot continue on the ſurface of our earth.

§. 356. At and upon mountains are ſprings, from which rivers and ſtreams ariſe, that ſupply the ſea in water. The ſea is never fuller, and ſprings yield their ſtreams a conſtant water. So that the water that has flowed out of ſprings muſt be carried back to them again. Only it is difficult to diſcover the way, in which it may happen. *Deſcartes* in his *Prin-*

Principia, P. 4. §. 64. holds, that the water in the earth is by its internal heat reſolved into vapour, which in the earth mount from one height to another, and at length reach to the mountains, and are there condenſed and changed into drops by the cold; which then collect in the cavities of the mountains, and on their quantity being increaſed, by their own weight ſeek an outlet. Several circumſtances favour this opinion. In the depths of the earth there is actually a quantity of water. Nor can we deny, that the water on the bottom of the ſea diſtributes itſelf through the intermediate ſpaces of the earth. Large damps or vapours have been found in mines, and that the ſprings there have been drained of their water, on the damps having found a free outlet. The like *Perrault* relates in his treatiſe *De l'origine des fontaines*, from the account given by a jeſuit of the mountain *Odmiloost* in *Sclavonia*. As ſtones, and ſome of them very large, were dug up on the top of the mountain to the depth of ten feet in the earth, there were found intire layers of ſtone, like a bedding, one over the other. As ſoon as they were taken out, below, thro' the vents or fiſſures of the bottom, a damp, like a ſtrong miſt, burſt forth with great rapidity, which continued for 13 days together. Scarce were 24 days at an end, when the ſprings, which were below round about the mountain, and watered the adjoining meadows, gave forth no more water, and therefore the graſs and herbs were withered up. He gives another inſtance from the

parts about *Paris*, where the evaporation, by opening a ſtone quarry, deprived the ſprings of their water. And thus the opinion of *Deſcartes* claims our aſſent. But there is a difficulty attends it, viz. that ſea-water is ſaline, and ſpring-water not ſo. Whither then goes the ſalt, on the ſea-water coming to be diſtributed through the earth? Some ſalt it will doubtleſs leave behind in the ſubterraneous veins, as earth and ſand take ſalt. But would not the ſalt be gradually ſo increaſed by the conſtant flow of ſalt water into the veins, that the following water could not be freed of its ſalt? How then ſhould ſpring-water continue ſtill ſweet? And hence *Perrault*, l. c. and *Mariotte* in his *Traité du mouvement des eaux*, P. 1. diſcourſe 1. aſſigned the riſe of ſprings and rivers to the rain. They ſuppoſed the rain to ſink ſo deep into the earth, till it meets with tophus or ſand-ſtone, or with clay, by which it is reſtrained from ſinking further; and that the rain-water flows on this bottom to the ſide where it ſlopes, till it finds an outlet under the earth. *Mariotte* by a peculiar examination of rain and ſnow-water, falling the year round on a particular ſpot of land, that gives water to a river, the *Seine*, for inſtance, found, that there is much more of it than is neceſſary to maintain the river at its mean ſtate a whole year round. And hereby *Mariotte* has gained his opinion no inconſiderable preference. But M. *de la Hire* in his reflections on rain-water and the riſe of ſprings, in the memoires for 1703, has ſhewn by

by many obſervations and experiments, that the rain and ſnow-water ſinks not above 16 inches deep into the earth, though it had no herbs or graſs to feed: and when graſs and herbs ſtand on the earth, reaches not to feed them. Yet we are here to conſider, that mountains contain more ſandy and ſtoney matters, and conſequently take not in the water, as the earth does, on which *de la Hire* made his trials. And thus we cannot deny ſprings all ſupply from the rain and ſnow-water. But neither can we deny, but a quantity of water forces into the earth downwards and ſideways immediately from the ſea. And as perhaps the ſalt of the pervading ſea-water is as ſubtlely reſolved by the ſubterraneous heat, as the water itſelf; ſo alſo ſprings may be enriched with water from the depths of the earth. And thus we are to ſeek for the riſe of ſprings as well in as without the earth. To the query, whether ſprings have more water from the air than from the earth? we ſhould be able to give a deciſive anſwer, could an accurate calculation be made, what quantity of water evaporated yearly from ſeas and rivers, and what quantity yearly was carried back into the ſea.

§. 357. In *Europe* and *America* there are mountains, upon and in which bodies lie, ſimilar to thoſe generated in the ſea, as ſea-animals and ſea-plants. The query is, how they came thither? Has it ever happened that the ſea formerly ſtood, by the ſtated courſe of nature, quite round the earth's ſurface ſo high, as are now the higheſt mountains? This

cannot

cannot be. For, whence ſhould this quantity of water come? Have animals and plants in a general deluge happened to have either freely gone up the higheſt mountains out of the ſea, or to have been forced up along with the water by the violence of the wind? Neither the firſt nor the laſt has any probability. Sea-animals ſeek the depths, when the ſea is boiſterous. Not only ſea-fiſh, but alſo ſuch animals as lodge in ſhells, and remove but little from the place of their origin, are found on mountains. The moſt violent winds at this day reach to between 12 and 14 feet deep into the ſea. And thus how could they poſſibly, at the time of a general deluge, carry along with them all manner of ſhell-fiſh and plants from the bottom of the ſea? And thus, we have good reaſon with M. *Morus* in his *New enquiry into the alterations that have happened in the earth*, P. 2. c. 6. to hold, that the mountains at this day in which marine bodies are lodged, were formerly the bottom of the ſea, and along with them raiſed by an earthquake above the ſea. A modern and undeniable inſtance of ſuch a riſing, the iſland in the *Archipelago* affords, of which mention was made (§. 348.)

CHAP.

CHAP. IV.

Of the MOTIONS of the WATER.

§. 358. THE ſprings of rivers on the earth's ſurface are more diſtant from the centre of the earth than the bottom of the bed of the river, in which the river continues its courſe, and the ſea, into which they at laſt fall. The more therefore the declivity or ſlope of the bed of a river, or its approach to the earth's centre, increaſes, the more the velocity of a river or ſtream increaſes (§. 33.)

§. 359. In order therefore to compare together either the increaſing velocities of a ſingle ſtream, or the different velocities of two ſtreams; we are in the firſt caſe to find the increaſing declivity, and in the ſecond, the different declivities, and from theſe to extract the ſquare roots. For, each declivity is to be conſidered as a ſpace, through which the water falls. And thus the greater the declivity, the greater the ſpace of the fall. But the velocities of falling bodies in different ſpaces, are to each other as their ſquare roots (§. 35.)

§. 360. The run or courſe of a ſtream is alſo accelerated by the preſſure, which the under water ſuffers from the upper. Give the bottom of a veſſel, which is full of water, a determinate aperture, and mark the time, in which it is emptied. Call the

the height of the veſſel 1. Then ſtick a pipe in the aperture of the veſſel, of a width with the aperture, and of a length, on adding the height of the veſſel, 4 times the height of the veſſel. Stop the pipe below with cork, and fill veſſel and pipe full of water. And then drawing out the cork ſtopple, the time, in which the veſſel is now emptied, to that, in which it was emptied before, is as $\frac{1}{2}$ to 1. The reaſon of this is eaſy. When the veſſel without the ſaid pipe is full of water, the water at the aperture of the veſſel is preſſed by the upper. This preſſure is 1, as the entire veſſel is conſidered as 1. But ſticking the pipe in the veſſel, the entire water below in the pipe undergoes a preſſure, which is to the former, as 4 to 1. Fell the water, which ſhoots out of the aperture of the veſſel the moment the ſtopple is drawn, from above down into the aperture; this would happen by the preſſure of gravity, which is to be conſidered as 1. Fell the water, which below ſhoots out of the pipe, on pulling out the ſtopple, from the height of the veſſel to the undermoſt aperture of the pipe; this would happen by the preſſure of gravity, which would be to the other, as 4 to 1. And as thus the water ſhoots out of the aperture of the veſſel, and out of the aperture of the pipe, hereby, viz. that it is preſſed by the upper; ſo this happens with a force, which is equivalent to the force of its fall. But the velocities of a falling body in different ſpaces are to each other, as their ſquare roots (§. 35.) Now as the ſquare root of 1 is = 1, and of 4 = 2; ſo the

run

run of the water out of the pipe ſtuck in is twice as quick, as out of the bare veſſel. Were therefore the time of efflux out of the bare veſſel one minute; the time of the efflux out of the pipe ſtuck in would be $\frac{1}{2}$ minute. And thus the higher the water ſtands in a ſtream, the greater the velocity of the water at the bottom. And hence the velocity of the lower part of a river increaſes inſtantly, when a number of ſhips come at once upon it, though the velocity of the upper is reſtrained. When rivers are about to run high, ſea-faring people diſcover it by the increaſing velocity of the under water. They commonly ſay, the *river moves at bottom.* M. *Buffon*, who has made this remark in his *General hiſtory of nature*, T. 1. P. 1. art. 10. reckons among the ſwifteſt rivers the *Tiger*, the *Indus*, the *Danube*, the *Irtiſh* in *Siberia*, and the *Malmiſtra* in *Cilicia*.

§. 361. And thus decreaſe continually the declivity of a ſtream the nearer it comes to its diſcharge into the ſea, yet its velocity may increaſe, as in its courſe it is continually ſwallowing up other rivers and brooks, whereby its weight of water is increaſed.

§. 362. When the run of a river turns quicker, as when for inſtance, it ſwells, the middle of the ſtream riſes. M. *Hupeau*, a man very knowing in bridge and dam building, has told M. *Buffon*, he once found, on meaſuring the different heights of the water in the river *Aveiron* at the banks and in the middle, that the water in the middle was three feet higher

higher than at the banks or fides. The reafon is, as in the middle is the ftrongeft draught, and its velocity diminifhes the effect of gravity. Whereas the water of a ftream is higher at the fides than in the middle, on the flood of the fea forcing into it. For, the middle draught runs tumbling into the fea, as being ftrongeft. So that the flooding fea forces in at the fides, and thus gives the water there an elevation.

§. 363. The ocean, whofe continuity reaches quite round the earth (§. 329.) has a conftant motion, by which it alternately fwells and falls. That called *flood*, this *ebb*. The ftate, in which the fea is, when no longer rifing, is called *high* or *full fea*; and its ftate when no longer falling, *low fea* or water. Ebb and flood regulate themfelves by the pofition of the moon and fun with refpect to the earth. The furface of the fea at Z, fig. 2. plate VIII. over which the moon ftands, rifes towards her. The furface of the contiguous parts in like manner rifes towards H and R, but in a lefs meafure. And rife the furface, the water under it quite to the bottom muft in like manner rife. And thus the diftant and adjoining fea-water, on which the caufe of the flood acts not, muft flow in to what is fwelled. At thefe diftant places there thus arifes in the time, in which the water under the moon fwells, an ebb. If the pofition of the moon fhifts; the water finks and falls again towards the parts, which it had before left. And thus at thefe places it is flood, and at the place, from

from which the riſen water falls, ebb. If the moon is at the antipodes in the meridian over N; the ſea riſes not only with them in N towards the moon, but alſo in the part Z, from which it is diſtant a ſemicircle of the heavens. And hence we obſerve at the ſhores in the ſpace of 24 hours twice ebb and flood. On the open ſea the flood begins, ſo ſoon as the moon reaches the ſix hour circle over R, and laſts till it comes to the meridian over Z. When from this laſt it turns to the weſt H, the water again decreaſes, till the moon reach the ſix hour circle in the weſt part of the earth. So ſoon as it quits this, and approaches the meridian at the antipodes over N, the water at Z begins again to grow. This ſecond flood laſts, till the moon reaches the meridian at the antipodes. Which ſo ſoon as it leaves, and again comes near to the ſix hour circle in the eaſtern horizon over R, the water at Z begins again to fall. And this ebb continues till the moon has reached the eaſtern horizon. Each flood and each ebb laſts for about ſix hours. *Newton* in his *Principia*, lib. 3. propoſ. 24. ſays, that the greateſt height of the growing water in deep and open ſeas follows the coming of the moon and ſun to the meridian in a ſpace leſs than ſix hours; as has been obſerved on the whole eaſtern extent of the *Atlantick* and *Ethiopick* oceans between *France* and the cape of *Good Hope*, and on the *Pacifick* ocean on the coaſts of *Chili* and *Peru*; and that on all theſe coaſts the

flood happens in about the third hour after the moon or ſun is come to the meridian, as well above, as under the horizon; except when the motion is ſomewhat reſtrained in certain ſhallow places. The moon riſes every day three quarters of an hour later than the foregoing day: and by ſo much too flood and ebb happen later. The younger *Caſſini* has found by obſervations made on ebb and flood, that the flood is regulated as well by the diſtance of the moon from the earth, as alſo by her declination, or diſtance from the equator. The flood is greater, when the moon is nearer the earth, than when farther from it. When the declination increaſes, the flood decreaſes. Alſo the greatneſs of the flood is different in the different diſtances of the ſun from the earth, and his different declinations or deviations from the equator. About the beginning of ſpring and harveſt the flood is greater than at the beginning of ſummer and winter. If then the moon is new, and appears in the ſame part of the heavens with the ſun; or if full and diſtant from the ſun 180 degrees; the flood is greater than when both have no ſuch poſition to each other. For inſtance, before the mouth of the river *Avon*, three *Engliſh* miles below *Briſtol*, the flood in the ſpring and harveſt at new and full riſes 45 feet, and at the quarters 25 feet only, as *Newton* mentions lib. 3. propoſ. 37. In the harbour of *Plymouth* the mean height of the flood is about 16 feet: and in the ſpring and harveſt

harveſt when ſun and moon are in conjunction, it exceeds the height at the quarters by between 7 and 8 feet.

M. *De la Condamine* in his voyage on the river *Amazon* between *Macapa* and the north cape in *Guiana*, in the part where the principal channel of the ſtream, on account of its many iſlands, is narroweſt, and eſpecially over againſt the great mouth of the *Arawary*, which falls on the north ſide into the *Amazon*, has remarked a circumſtance, which is peculiar. In the three days next the full and new moon, and when the flood runs higheſt, the ſea reaches its height in one or two minutes time; whereas otherwiſe it takes ſix hours nearly. At the diſtance of a mile or two a dreadful roaring is heard, by which the flood is announced. The nearer it approaches, the greater the roaring. And ſoon after a ridge or mountain of water is ſeen between 12 and 15 feet high, then a ſecond, a third, and ſometimes a fourth, coming on with great rapidity, one upon the back of another, which take up the whole breadth of the channel. Theſe waves come on with amazing quickneſs, and ſweep along with them every thing that ſtands in their way.

The changes, that happen in the direction, extent and time of the ebb and flood, ariſe from the winds, the rivers and other circumſtances, which are to be ſought for partly in the ſea, partly in the firm land.

§. 364. The ocean conſtantly moves from eaſt to weſt. According to *Varenius* in his *Geographia generalis*,

neralis, lib. I. c. 14. prop. 7. This motion is uncommonly violent in the *Magellanick* ſtraits, in the gulf of *Paria* and in the ſea of *Canada*. The *Atlantick* ocean flows towards, and the *Pacifick* ocean from *America*. From *Japan* it flows towards *China*. And the *Indian* ocean runs to weſtward in the ſtraits of *Java*, and thro' the narrow guts of the other *Indian* iſlands. Among the cauſes of this motion we may reckon the conſtant eaſterly breeze on the ſea under the line (§. 383.) eſpecially as by the conjecture of the author of the *Recherches phyſiques & mathematiques ſur la theorie de vents reglés, ſujet proposé par l'academie des ſciences de Pruſſe*, for the year 1746. (§. 12.) it ſhould be ſo ſtrong, as in two years to carry round the earth a well equipped ſhip, ſo ſhe met with no impediments in her courſe. The other cauſe of the inceſſant motion of the ſea weſtwards, may be the force, which the flood produces. For, this flood goes from eaſt to weſt. Alſo the motion weſtwards at the time of flood, is much ſtronger than at the time of ebb.

§. 365. As the uninterrupted motion of the ocean from and to the ſame quarter, ariſes in the manner of a ſtream or current, it may be called a *ſea-current*. Beſides this general ſea-current, we find at ſea ſeveral other currents, mentioned by *Varenius*, l. c. prop. 23—30. For inſtance, in the *Atlantick* ocean on the coaſt of *Guinea*, the water moves from weſt to eaſt, flowing from cape *Verde* to the bay of *Ferdinando Pao* with ſuch violence, as that ſhips may

may come in two days from *Moure* to *Rio de Benin*, a courſe of 150 leagues, whereas in returning back they take ſix or ſeven weeks. At *Sumatra* the ſea runs from ſouth to north into the bay of *Bengal*. The cauſes of theſe currents are ſtill more unknown than the cauſes of the inceſſant current from eaſt to weſt.

§. 366. A fluid matter whirls round when moving in a curve line about a point. To this two forces concur: one to impel the fluid from a point of the circumference, as for inſtance, from A to the centre C, fig. 8. plate II. and the other from A to the point D along the line A D (§. 100.)

§. 367. A whirlpool therefore ariſes, when a ſtream ſtrikes againſt a reſiſting matter, or obſtacle; which ſuppoſe to be at A, and the ſtroke to happen in the line C A, fig. 8. plate II. As A is an obſtacle; the impinging water will be repelled back to C, as a centre, in the line A C, and thus acquire a centripetal force. But as moreover the water impinging on A is fluid, it will be ſeparated, and impelled ſideways to D, for inſtance; and hereby it gains a centrifugal force. And thus by both forces it begins to deſcribe a curve line, which is ſo long renewed, as the following water flows on to C A. Come the water impelled in the curve line A E to E, it has a conatus to proceed in a right line from E (§. 10.) whereas by the reſiſtance of the contiguous water it is impelled in the line E C to the centre C; ſo that it muſt take its courſe in the curve line E L. In

this manner it comes into a circular motion. The reſiſting matter may be either any firm and immoveable thing, as a wall, a ſhore, for inſtance; or a water at reſt and confined; or a contrary current of water. And hence whirling circles ariſe in the water, when in its courſe acting againſt the flooding ſea-water. In like manner at bridges whirling motions ariſe, on the ſtreaming water being reflected back from the piers. And ſo the *Auſtrian* whirlpool in the *Danube* takes its riſe at the diſtance of half an hour below *Grein*, where the water there ſtrikes againſt a huge rock. The author of the *Reſearches into the ſea*, publiſhed in 1750, in P. 2. reſearch 3. p. 195—215. gives an account of the peculiar nature of this whirlpool in the *Danube*, and refutes the erroneous opinion commonly entertained; as if in that part of it a portion of the water of the *Danube* ſunk thro' a ſwallow or abyſs down to ſubterraneous depths below. In the ſame writing, reſearch 3. p. 137—156. we have a circumſtantial deſcription of *Charybdis* near *Sicily*, and of the *Mael-Strom* near *Norway*.

§. 368. The ſurface of a whirlpool is deeper towards the middle than towards its outſide, the water riſing towards the outſide by the acquired force, whereby it tends to recede from the centre. Come therefore a body, which is lighter than the water, into its whirl; it will be impelled to the middle by a two-fold cauſe; firſt, by its gravity, on account of the declivity of the water; ſecondly, by its centrifugal force,

force, as being leſs than that of the water; as having a leſs weight than the water, on which it floats (§. 97.) M. *Saulmon* has illuſtrated this by a variety of trials made with bodies, ſunk into a whirl, and deſcribed in the memoires of the academy of ſciences for the year 1714.

SECT. III.

Of the EARTH's Atmoſphere.

§. 369. THE air encompaſſing the earth, in which as well particles of water, as other matters float, is called its atmoſphere.

CHAP. I.

Of the Connection of the AIR with the EARTH.

§. 370. AS air is lighter than water (§. 115. and 67.) we might be apt to imagine, for the very ſame reaſon, for which the water, by the earth's circular motion, is nearer its centre than the ſolid earth (§. 342.) that the air ſhould be nigher it than the water. And thus it remains to enquire, why the air is, notwithſtanding, raiſed far above the water and ſolid earth. Were it not

elaſtick, it would come to lodge both in the earth and under the water. The elaſticity of a cubick foot of air is far more intenſe than its gravity (§. 117—119.) And as thus the air, on account of its ſpecifick levity, ſhould be nigher the earth's centre than the water; ſo on the contrary it is ſo expanded by its elaſticity, as to fill not only earth and water, but alſo extend itſelf far above them in the heavenly ſpace.

§. 371. By its gravity the atmoſphere conſtitutes a part of the earth, and thus turns round with it about its axis. For, the very ſame cauſe, that gives the earth its circular motion, acts alſo on the atmoſphere.

§. 372. By this motion, under the equator, its decreaſe of gravity is greater than towards and under the poles. It muſt therefore ſtand higher above the equator than above the poles.

CHAP II.

Of the Degrees of Heat and Cold in the Atmosphere.

§. 373. THE degree of heat, which we perceive in the atmoſphere, ariſes from two cauſes: from the ſubterraneous fire, which extends its effect through the earth's ſurface; and from the fire, which is contained in the atmoſpherical matters, and put into motion by the rays of the ſun. For, from the defect of this two-fold fire, which happens

happens on high mountains, ariſes there the degree of cold, which even in ſummer is not diminiſhed. (§. 351, ſeq.)

The degree of heat of the atmoſphere at the earth is therefore to be conſidered as a whole, conſiſting of two parts; the one having its riſe from the ſubterraneous fire, and as being ſomewhat conſtant, M. *Mairan* calls the *ground-heat.* The other part, excited by the ſun's rays in the atmoſpherical matters, we may call the *ſolar heat.* The whole degree of heat, ariſing from the ground and ſolar heat together, we may call the *integral heat of the atmoſphere.* This heat, by the ſtated courſe of nature, is greater on the longeſt than on the ſhorteſt day. By *Amantons*'s obſervations and experiments, in the latitude of *Paris*, that is, its diſtance from the equator, the integral heat on the noon of the longeſt day, to the cold in the ſhorteſt, is as 60 to 51 $\frac{1}{2}$, or as 8 to 7 nearly. His diſſertation thereon, and the deſcription of the thermometer he uſed for the purpoſe, are contained in the memoires of the academy of ſciences for the year 1702. On the contrary, M. *Mairan* in the memoires for the year 1719, in his diſſertation on the general cauſe of the cold in winter, and the heat in ſummer, ſhews that the ſun's heat on the longeſt day to the ſun's heat on the ſhorteſt, in the latitude of *Paris*, is as 66 to 1. From this he concludes, that the conſtant ſtock of heat, or the ground-heat, in the latitude of *Paris*, is 393 times

times as great, as the degree of heat on the ſhorteſt day, ariſing from the ſun only.

The proof of the ratio of 66 to 1 conſiſts of the following particulars: The times, conſidered in the ſaid ratio, are two inſtants; the one at noon in the ſummer ſolſtice, and the other at noon in the winter ſolſtice. In both ſolſtices the rays of the ſun, falling on a plane, make therewith an oblique angle; which on the ſhorteſt day is more oblique than on the longeſt. Suppoſe the oblique angle on the longeſt day to be A H R, fig 9. plate XIV. and that on the ſhorteſt B H R. Both angles are to be conſidered, in order to find the difference of heat in both the ſolſtices. For, the rays of the ſun act on the earth's ſurface as impinging lines or threads of a fluid matter. Now the more oblique they are, the weaker their ſtroke. For, happen it direct, or under a right angle; an impinging line applies its whole force. And thus again impinge it oblique, it does ſo with a part only of its force (§. 89.) If, beſides, a quantity of threads moves at the ſame time againſt a ſurface; the number of them, which come on a determinate ſurface, is fewer, the more oblique their direction towards it. For, the more oblique you hold a veſſel, for inſtance, to the rain, the leſs you catch with it. In order therefore to meaſure the force of oblique incident rays of the ſun by the different magnitudes of the angles, you are to multiply in two different angles the obliquity of

of each by itſelf. For, a ſtroke is by ſo much greater, by how much the number of the impinging rays is greater. For inſtance, if the ſtroke = 1, and the number of the ſtriking rays in like manner = 1; the magnitude of the ſtroke is = 1. If the ſtroke = 1, and the number of the rays = 2; the ſtroke is twice as great as the preceding. And thus if the ſtroke = 2, and the number of the rays = 2; the ſtroke now is four times as great as the firſt. The meaſure of the obliquity and quantity of the incident rays are the ſines of the angle, under which they are incident or impinging (§. 89.) Now the ſine of incidence A C, fig. 9. plate XIV. of the rays on the noon of the ſummer ſolſtice at *Paris*, to the ſine of incidence B D on the noon of the winter ſolſtice there, is as 90370 to 30375, that is, as 3 to 1 nearly. And thus the intenſity of the ſun's rays on the noon of the ſummer ſolſtice, to that on the noon of the winter ſolſtice, is as 9 to 1; ſo you multiply 3 by 3, and 1 by 1. The more oblique the ſun's rays paſs through the atmoſphere, the fewer of them come thereby on the earth's ſurface. So that in the caſe of two oblique incident rays we are alſo to conſider, what ratio the number of the ſun's rays, that under one angle come through the air, has to the number of thoſe, that under another angle force through the atmoſphere. At *Paris* on the noon of the longeſt day twice the number of rays paſs through the air, as on the noon of the ſhorteſt day. And thus you are to multiply 9 by 2, and 1

by

by 1. And in this manner the intenſity of the ſun's rays at *Paris* on the noon of the ſummer ſolſtice, to that of the ſun's rays on the noon of the winter ſolſtice, is as 18 to 1. Fourthly, we are to conſider the length of the day and the ſhortneſs of the night. The longer the day, and the ſhorter the night, the more intenſe is the ſun's heat. At *Paris* the longeſt day is to the ſhorteſt, as 2 to 1 nearly. And the ſhorteſt night at the ſummer ſolſtice to the longeſt night at the winter ſolſtice, is as 1 to 2. And therefore at the ſummer ſolſtice *Paris* gains the whole day through twice more heat, and loſes the night through twice leſs heat than in the winter ſolſtice. And thus we are to multiply 18 by 4, and 1 by 1. So that at *Paris* the ſun's heat on the longeſt day, to the ſun's heat on the ſhorteſt, is as 72 to 1. But as the ſine A C of the ſun's meridian height on the longeſt day is not quite three times as great, as the ſine B D of the meridian height of the ſun on the ſhorteſt day; M. *Mairan* makes the proportion as $70\frac{1}{2}$ to 1 only. In this reduction he at the ſame time had a regard to the refraction of the rays, by which on the day of the winter ſolſtice the ſun appears higher in the meridian at *Paris* $3' 6''$; whereas on the day of the ſummer ſolſtice about $27''$ only, than it really is (§. 188.) Fifthly and laſtly, we are to conſider the ſun's diſtance from the earth. On the ſhorteſt day, it is nearer the earth than on the longeſt. The more diſtant it is, the weaker it acts. The ſun's diſtance in the ſummer ſolſtice to its

its diſtance in the winter ſolſtice, is as 30 to 29 nearly. Now the denſities of the rays at different diſtances are to each other inverſely as the ſquares of the diſtances (§. 145.) The ſquare of 30 is 900, and the ſquare of 29 is 841. But 900 : 841 : : 15 : 14. And thus we have $70\frac{1}{2}$ to multiply by 14, and 1 by 15. So that the ratio comes out as 66 to 1.

M. *Mairan* preſuppoſes, that the ground-heat on the longeſt and ſhorteſt days is one and the ſame. And thus we are to conſider the integral heat on the longeſt day, and the integral heat on the ſhorteſt, as two integers or wholes, each of which conſiſts of two parts, and the one differs from the other by one part only. This part in the integral heat on the ſhorteſt day is the ſun's heat therein, as being leſs than the ſun's heat on the longeſt day. In two ſuch wholes or integers the leſs part is to the difference of both the integers, as it is to the difference of the greater and leſs parts. For inſtance, ſuppoſe one whole to be = 36, and the other = 24; and the firſt to conſiſt of 30 and 6, and the ſecond of 18 and 6. The difference between both the wholes 36 and 24 is = 12; and the difference between the greater and leſs 18 and 6 is alſo = 12. The one difference is equal to the other. And thus 18 : 12 : : 18 : 12. We may therefore conclude, as the difference of the greater and leſs parts 12 is to the leſs part 18; ſo is the difference of the greater and leſs wholes 12 to the leſs part 18. That is,

12 :

12 : 18 : : 12 : 18. If therefore the difference of the greater and lefs parts 12, and the lefs part 18, and the difference of the greater and lefs wholes 12, are given; we find the lefs part by the rule of three, fo we multiply 18, as the lefs part by 12, as the difference of the greater and lefs whole, and divide the product thence arifing 216 by the difference of the greater and lefs parts 12; namely, $\frac{216}{12}$ (18.

As the fun's heat on the longeft day to the fun's heat on the fhorteft, is as 66 to 1; fo is the difference of the greater and lefs degrees of heat of the fun, as of a greater and lefs, = 65. And as the integral warmth on the longeft day is to the integral warmth on the fhorteft, as 60 to $51\frac{1}{2}$; fo is the difference of both thefe degrees of heat, as of a greater and lefs whole, = $8\frac{1}{2}$. So that the partial heat of the fun on the fhorteft day is = $\frac{17}{130}$. For, $65 : 1 :: 8\frac{1}{2} : \frac{17}{130}$. If now $\frac{17}{130}$, as the partial heat of the fun on the fhorteft day, is as a part deducted from the integral heat $51\frac{1}{2}$; there remains over $\frac{6678}{130}$, as the other part of the integral heat on the fhorteft day; that is, the magnitude of the conftant ground-heat. Now, $\frac{17}{130} : \frac{6678}{130} :: 1 : 393$. And thus the partial heat of the fun on the fhorteft day to the conftant ground-heat, is as 1 to 393; fo you calculate and conclude by the principles affumed.

§. 374. The degree of cold in the atmofphere may therefore arife from two caufes: (1.) When the rays of the fun, on account of their increafing obliquity, begin to act with lefs force on the atmofphere

ſphere and earth. And (2.) When the internal fire of the earth is hindered to act through its parts up to the atmoſphere. Among the cauſes, which reſtrain the paſſage of the ſubterraneous heat, are to be reckoned ſaltpetre and other ſalts. And hence in *Siberia* and ſome other parts of the continent of *Aſia* between the 55 and 60 degrees of latitude, there is a far ſeverer degree of cold, than at *Tornea* in *Bothnia*, which lies under the latitude of 66 degrees (p. 191.)

CHAP. III.

Of the Cauſes of the decreaſing and increaſing Preſſure of the AIR.

§. 375. THE aſcending watery vapours increaſe the weight of the air. And thus by rain it is leſſened. Yet this diminution and increaſe appear but in a ſmall degree by the barometer. In the memoires of the academy of ſciences for the year 1717 it is ſaid, that *De la Hire*, in the months of *September* and *October* in 1716, when it rained very hard, found that 27$\frac{1}{8}$ lines high of rain had fallen. And all *January* throughout the ſnow having fallen as deep as had ever happened, the water from ſo uncommon a quantity ſtood only 29$\frac{1}{8}$ lines high. And thus ſuppoſing, there had been ſo much water at once in the air, as in the ſaid time had fallen either in rain or ſnow; it would come to the very ſame thing, as if the veſſel with the quickſilver

quickſilver had been plunged 28 lines deep under water. The quickſilver in the tube would riſe 2 lines high (§. 227); the twelfth part only of the entire change, which the barometer exhibits from the loweſt to the higheſt place (§. 116.)

§. 376. And thus increaſe the aſcending watery vapours the weight of the air; they on the contrary weaken its ſpring, juſt as water deprives dry wool, dry cat-gut, of a part of their elaſticity. And if thus directly by the weight of the mounting watery vapours, the under air is heightened in elaſticity, as being compreſſed thereby: ſo on the other hand it may be diminiſhed in this its elaſtick force, either juſt ſo much, or even ſo much more, by the moiſture. And hence the quickſilver, in a tract of good weather in ſummer, is wont to fall on the ſpring of the air decreaſing by the increaſing moiſture; either ariſing from the earth, or conveyed thither by the ſouth and weſt winds.

§. 377. If the air is dry, it therefore proves elaſtick. And hence the quickſilver at times is wont to riſe in rain; but ſometimes in rainy weather to remain ſtanding at its low place. This happens when the air, notwithſtanding the rain, acquires a freſh ſtock of moiſture.

§. 378. By the increaſing cold in winter the elaſticity of the air is in like manner increaſed, as the vapours are froze in the air. And hence the quickſilver in the barometer, on the increaſing cold in winter, uſually riſes.

§. 379.

§. 379. But when the air is cold, not only its ſpring, but alſo its gravity increaſes: for, by the cold it is contracted. And thus other air from the neighbouring parts forces into it. So that the cold air turns denſer, and conſequenly heavier. In like manner the air turns denſer and heavier, when that in the neighbouring parts is warm: for, by warmth it expands.

This heat and cold, by which the air turns denſer and heavier, may ariſe at a certain height, without being perceived in the part, where we live, and marked out in the thermometers. And thus hail is wont to fall in the hotteſt days of ſummer: which ariſes hence, that the watery vapours and drops of rain are froze at a certain height.

The inſtruments, which indicate the decreaſing and increaſing denſity of the air, are called *manometers*; and thoſe, whereby the moiſture of the air is diſcovered, *hygrometers*, or *notiometers*, or *weather-balances*. The manometer baron *Wolfius* deſcribes in his *Experiments*, P. 2. c. 4. And the hygrometer, c. 7.

As the riſing and falling of the quickſilver in barometers are not at all times owing to the decreaſing and increaſing gravity of the air; they ought not in propriety to bear this name.

CHAP. IV.

Of the WINDS.

§. 380. FOR any remarkable motion, or a wind, to arife in any part of the átmofphere; either the expanfive force of the air muft there be diminifhed; or the fpring of the contiguous air either heightened or leffened; or a contiguous part of the atmofphere forced thither by a certain degree of violence. Happen nothing of all this; the parts of the atmofphere act with equal force againft each other, and confequently no part of it moves.

§. 381. Arife a wind in a place, from the elaftick force of the atmofphere being there diminifhed; the quickfilver in the barometer falls at the fame time. But arife it hence, that the fpring of the contiguous air has been diminifhed, the height of the quickfilver may remain unchanged. This happens, when the recefs of the air, which goes to the neighbouring part, is ever replaced by frefh and equally elaftick air. An inftance to this purpofe baron *Wolfius* adduces in his *Ufeful Experiments*, P. 2. §. 44. from his own experience. Sometimes the quickfilver falls quick one or more lines, and in a little time after a violent wind comes on, viz. when the fpring of the air, for a tract of many miles in length, is weakened at once; and the barometer fo diftant from the place, from which the

air,

air, by virtue of its intenſer elaſticity, forces in, that its motion can after ſome time only reach the part where the barometer ſtands. If the wind has begun its courſe towards a certain quarter, it continues in that direction, and thus divides the atmoſphere, when alſo elaſtick in an equal degree. At the place, where this happens, the quickſilver therefore falls; as the upper air is prevented from preſſing on the under. This may be confirmed by a peculiar experiment, for which purpoſe *Hawkſbee* deviſed an inſtrument, deſcribed by baron *Wolfius*, l. c. §. 43.

§. 382. The cauſes, by which the elaſticity of the earth's atmoſphere is changed, are partly variable, as moiſture, elaſtick vapours, heat and cold; partly conſtant, as the motion of the earth on its axis, and the action of the ſun and moon on the air. From the laſt cauſes ariſe the *conſtant winds*, and from the firſt, the *ſhifting* or *variable* ones, which have no fix'd period, in which they begin and ceaſe, and return again. A diffuſe diviſion of winds into their ſeveral ſpecies *Varenius* gives in his *Geographia Generalis*, l. 1. c. 20, 21.

§. 383. By the heat of the ſun, and motion of the earth on its axis, on the ſea under the line a conſtant eaſterly breeze is produced. Take, for inſtance, three points on the earth's ſurface; one of which A, fig. 12. plate VIII. is at the weſtern horizon, C at the eaſtern, and B in the middle between both. Suppoſe the ſun to be over C. Under

it the column of air is the moſt rarified by its heat. Move the earth on its axis from weſt to eaſt, and thus come it at B into the place, where before C was; the column of air over B will be the moſt intenſely rarified by the heat of the ſun, and thus increaſe its expanſive force. Now as the former column of air, which no longer ſtands under the ſun, gradually loſes its acquired heat, and conſequently contracts; ſo the air from the now heated column at B forces into it. But as the cooled air-column acquires more maſs of air, and the heated has leſs; ſo the air flows in from the cooled back to the heated column. Now advance the place B with the earth's motion, and come A in its place; B will be cooled, and A heated. The air-column over B was already become denſer by the retroflux of the air from the eaſt. And now it is ſtill denſer; and therefore it will neceſſarily move towards A. And in this manner a wind blows from eaſt to weſt.

The earth at the time only, when day and night are equal, is ſo ſituated to the ſun, that for a whole day it is ſeen in the equator. After this day, from one day to another it acquires, till a certain time, a continually obliquer poſition to the ſun. This happens in the one half year to the north; and in the other, to the ſouth. If now the north ſide is heated, and the ſouth ſide cooled; the air flows from ſouth to north. If on the contrary the ſouth ſide is heated, and the north ſide cooled, the air flows from north

to

to south. As now, on account of the diurnal rotation of the earth, the air, by the heat of the sun, moves from east to west, as along C B fig. 5. plate 1. and on account of the decreasing distance of the sun from the equator along C D; there arises a compound motion in C A (§ 13.) In this manner the wind blows under an oblique angle towards the equator. This happens at sea, and would happen on the whole surface of the earth, consisted it throughout of one and the same matter, and had it no hills.

The heat of the sun is not its only action on the earth. In the last part of the physicks we will, besides, exhibit another force, with which sun and moon act on the earth. Whether and how far it is to be reckoned among the causes of the constant winds, we will there enquire.

§. 384. The strength or intenseness of a wind arises from the quantity of the parts of air, that impinge on a surface, and from the velocity, with which they are impelled (§. 37, 38.) The quantity of the parts of air, by which a surface is struck on, is to be estimated by the magnitude of this surface. How the velocity of each several wind may be discovered and calculated, professor *Kraft* teaches us in his *Observationes Meteorologicæ*, §. 10. inserted in the *Comment. Petropolit.* T. 9. p. 344, &c. Baron *Wolfius* in his *Elementa Aerometriæ*, published in 1709, has described an anemometer of his own devising, by which we may accurately determine, how much one

wind blows ſtronger than another. In the memoires of the academy of ſciences for the year 1734 we find five anemometers, among which this of baron *Wolfius* is in particular mentioned. The fifth, which is circumſtantially deſcribed, p. 169, was deviſed by M. *D' Onſ—en—bray*, and on a paper ſhews all the winds, blowing within the 24 hours; and beſides, at what hour each wind had ariſen and fallen; and at the ſame time their different velocities, or relative forces and powers.

CHAP. V.

Of the Emphatick or Shining METEORS.

§. 385. THE heavens quite around appear to a ſpectator in all the points of an unaſſignable diſtance to reſt on the earth, and to exhibit a circle. This circle ſeems to divide the heavens into two hemiſpheres, and is therefore called the *viſible horizon*. Whereas the *true horizon* is that circle, which actually divides the heavens into two hemiſpheres. Each ſeveral point of the true horizon is diſtant from the *zenith* or *vertex* 90 degrees, or a quadrant. And reckoning from the zenith in a great circle 180 degrees; the point where the reckoning ends, and to which a line may be drawn from the zenith through the earth, is called the *nadir*. So that the true horizon is alſo 90 degrees diſtant from the nadir.

§. 386.

§. 386. Suppose H R, fig. 3. plate XI. to be the true horizon, and A B the apparent, and the spectator to stand in O. Suppose the curve line O L D to be the limits of the earth's surface, and A H E the limits of the earth's atmosphere, in which the rays of light are refracted. If below the true horizon H R a ray S E comes from the sun S into the atmosphere at E; it is refracted towards the earth's semidiameter E C, as being the perpendicular, (§. 164), and goes in the line E D A on to A, the extremity of the apparent horizon, as it rakes along the earth at D. The particles of the earth's atmosphere reflect a part of the rays impinging on them, to the eye of the spectator in O, and cause a light, which is called the *twilight*. And arising before the going up of the sun, it is called the *morning-twilight*; but after the going down of the sun, the *evening-twilight*. This last ends, when the sun is about 18 degrees below the western horizon; and that other begins, when the sun has the same depression under the eastern horizon.

§. 387. When the rays, that go up into the vapours of the air from the sun below the eastern horizon along the earth's surface, produce in the opake particles of the vapours, that vibration, from which the red of the light takes its rise; the *dawn*, or *morning red* appears. In the same manner the *evening red* or *twilight* is produced. The more distant and high these vapours extend over the horizon, the more distant extends the morning and evening red:

and the denſer the vapours, the more vivid the red.

§. 388. If between the eye and a luminous body a matter partly tranſparent interpoſes, exceeding in denſity both the mediums between itſelf and the luminous body and the eye; the eye may perceive in this matter partly at the ſides of the luminous bodies certain figures, having a reſemblance with them; partly certain circles and rings which appear either white or coloured. For, the rays, which fall from the luminous body under an oblique angle in to the tranſparent matter, are refracted as well in the going in, as going out (§. 164.) Theſe incident rays are mixed. If divided by the refraction, and carried to the eye, they excite in it a colour (§. 219.) If the rays, which flow from the luminous body, as from the vertex of a cone, to the tranſparent matter, as the baſe of the cone, are refracted quite round in one and the ſame manner; a coloured circle muſt appear in the eye; ſuch as the eye obſerves in the night time in a room, when between the eye and a burning candle there is a vapour, that is partly opake. If the rays in going out of ſuch a matter are ſo refracted under different angles, that at laſt all the ſeven colours mixed together come into the eye, it obſerves a white circle (§. 219.) Such a circle or ring, appear it white or coloured, is called a *halo*, when appearing round a ſtar. Such a halo may now have a ſmall, again a large diameter, as the denſity of the matter, neceſ-

ſary for the proper refraction, is ſideways near to or far from the ſtar. In like manner may a ring be formed, not incloſing the ſtar, the ſun, for inſtance, or the moon, when the ſtar is withoutſide the ſpace of the refracting matter. Further alſo, a part only of a ring may be viſible, when the refracting matter, out of which the rays are refracted to the eye, occupies only an arch. This arch may obvert to the ſtar now the concave, again the convex ſide, according to the curve line, in which the refraction happens.

By the refraction the image of the ſun or of the moon appears, when the rays, which fall from the ſurface of the ſun, or of the moon, on a denſe part of the waving or floating vapour, are carried to the eye together, or in that mixture, with which they fall on the vapour. And thus appear the images of the ſun and moon at the horizon, when they have a certain degree of depreſſion under the horizon (§. 188.) But if the ſun and moon are at the ſame time above the horizon; their images are called *parhelia* or *mock-ſuns*, and *paraſelenæ* or *mock-moons*.

Reflection alſo may produce a mock-ſun, or a mock-moon, when by the vapours ſtanding juſt oppoſite to the ſun or moon, the rays, which they receive from the directly oppoſite ſurface of the ſun or moon, are fully reflected to the eye. Such vapours are to be conſidered as mirrours.

If a tail appears at a mock-ſun or mock-moon, it ariſes from the refraction, which the ſingle rays of the

the ſun or moon undergo in the vapours at their images.

§. 389. If, according to *Deſcartes*'s directions in his book *De meteoris*, c. 8. you ſo hang a glaſs globe B C D, fig. 1. plate VI. filled with water, in a room, that a ray of the ſun A B falls on it; the eye may obſerve at the point D the ſeven primitive colours one after another, on now raiſing, again lowering the ball by a ſtring. The ſpectator has the ſun in his back, and the globe of water in his ſight. The ray A B is refracted in going in at B towards the perpendicular (§. 164.) and goes on to C, and is in part reflected to D; and in going out, refracted from the perpendicular, and proceeds to E, where the eye may be ſuppoſed to be. Imagine a right line E M drawn through it, running parallel with the ray A B, and which may be drawn through the eye backwards through the centre of the ſun. Form the ray D E, refracted out of the globe, an angle of 42 degrees and 2 minutes with the line E M, the point D appears red. If the globe is ſo far let down, that D E forms with E M an angle of 40 degrees and 17 minutes, the point D appears of a violet colour. Now ſo the globe be let down ſlowly from the firſt height to the laſt; the eye comes to view the other colours, contained between the red and violet, gradully in the order, in which they exhibit themſelves, on letting a ray of the ſun fall through a glaſs priſm. Admitting into the room ſo many rays of the ſun only, as are neceſſary to

to enlighten the globe, and holding in the place, where the eye ſhould be, a white paper, all the colours ſhew themſelves at once thereon.

§. 390. From this the *ordinary* and *inner rainbow* may be explained, in which the red colour has the uppermoſt, and the violet the undermoſt place. The matters, in which the rainbow is produced, are the drops falling from a cloud, on which the oppoſite ſun or oppoſite moon ſhines. For, we ſometimes not only ſee the legs of the rainbow, ſtanding on the roofs of houſes and on the earth, but alſo through the legs freely ſee the trees and houſes behind them. All this the eye could not obſerve, did the rainbow ariſe in the clouds, as they extend not quite down to the roofs of houſes and to the earth. But drops of rain are adapted to produce colours, as in the manner of glaſs globes filled with water, they can refract and reflect the incident rays. Suppoſe the eye to be in O, fig. 2. plate VI. between the ſun S, and the ſurface of rain V H C; and in this ſuppoſe two falling drops to occupy the places T and K; ſuppoſe one ray D E to fall from the ſun on the drop K, and another P S on the drop T; conſidering the prodigious magnitude of the ſun, and the ſmall height of the falling drops, we may very well affirm, that the eye is between the ſun and the ſurface of rain. Draw through the eye the line O F parallel with the ſaid rays; the incident rays D E and P S are refracted at E and S in entering the drops, and go on to the points K and T. From theſe points they

they are in part reflected to *n* and Q, and in the going out at *n* and Q, again refracted. Suppose therefore the ray *n* O, falling out of *n* into the eye, to form at O with O F an angle of 42° 2′; and the ray Q O, falling out of Q into the eye, to form at O an angle of 40° 17′; the eye at once sees red and violet. Now if there are between both these drops five more, out of which five rays come to the eye, forming with the line O F a fivefold angle, whose magnitudes are ever decreasing from the angle *n* O F to the angle Q O F; the other five colours between the red and violet exhibit themselves to the eye.

The drops, in which the incident and excident rays are so refracted, that they exhibit the colours, may for shortness be called the *colouring* or *tinging drops*; and a line, in which are seven drops, one over the other; each of which by a peculiar refraction excites a peculiar colour, may be called a *row of colouring drops*. The entire surface of rain, which extends to right and left before the eye of the spectator, consists of innumerable such rows, so near, that their interstices cannot be observed; so that the colours must appear to go on uninterrupted to right and left in the surface of rain. In each row the ray *n* O, coming out of the uppermost drop into the eye, must form with the line O F an angle of 42° 2′; and the ray Q O, going out of the undermost drop to the eye, with the same line O F an angle of 40° 17′. Lines, falling from different points of a

surface

ſurface on a diſtant and common point, through which a line is drawn, and with this line forming equal angles, go in a circle round this line. So that the initial points in the ſurface, from which the lines, drawn to the common point, take their riſe, muſt in like manner be in a circle. The periphery of the baſe of a cone ſhews this diſtinctly. And thus in the ſurface of rain the rows of tinging drops proceeding to right and left muſt exhibit a circle with ſeven colours, of which the red is the uppermoſt, and the violet the undermoſt; that is, exhibit the ordinary and inner rainbow; when the line O F running parallel with the incident rays, forms with the ray *n* O, coming to the eye, an angle of 42° 2′, and with the ray Q O an angle of 40° 17′. As the drops fall, the colours vaniſh directly with their fall. But as others come immediately into their place, theſe immediately give forth new colours. In this manner the rainbow appears to continue for ſome time; but in reality it conſiſts of a number of rainbows, ſucceeding each other in imperceivable times.

§. 391. If above the rows of the tinging drops, which exhibit the ordinary rainbow, there are ſuch other rows, out of whoſe drops the incident rays of the ſun or moon, after a double reflection and a double refraction ſo come to the eye, that the ray B O, fig. 2. plate VI. forms with O F at O an angle of 54° 7′, and the ray *m* O with O F at O an angle of 50° 58′ 39″; there appears another beſides above the ordinary rainbow, called the *outer*, the *upper* and *extraor-*

dinary

dinary rainbow, in which the red colour is the undermoſt, and the violet the uppermoſt. That the colours appear under the circumſtances determined, and have the ſaid order among themſelves, *Deſcartes*'s experiment again ſhews, on hanging a glaſs globe, filled with water, in a room at a thread drawn over a pulley, and ſo pulling it up by this thread, that the rays, coming out of the globe to the eye, ſhall form with the line O F the mentioned angles.

§. 392. The breadth of a rainbow conſiſts in the ſpace between the uppermoſt and undermoſt colours; and conſequently in the difference between the two angles, which the rays, coming out of the uppermoſt and undermoſt drops to the eye, form with OF. The difference between $42^\circ\ 2'$ and $40^\circ\ 17'$ is $1^\circ\ 45'$. And ſo this is the breadth of the inner and under rainbow. The difference between $54^\circ\ 7'$ and $50^\circ\ 58'\ 39''$ is $3^\circ\ 8'\ 21''$. And thus ſo great appears the breadth of the outer and upper rainbow.

§. 393. The more opake the ſpace behind the ſurface of rain, and its rows of tinging drops, the more vivid are the colours of the bow. For, in ſo far as the ſpace behind the ſurface of rain is opake, in ſo far forces through it to the tinging drops no adventitious light, which can mix with the rays, refracted out of them to the eye, and conſequently weaken their intenſeneſs. In particular, the ſpace behind the ſurface of rain muſt be very opake, for the

the upper and outer rainbows to exhibit vivid colours. For, as at the reflecting point in a drop of water ſome rays always go to the hinder ſpace; ſo this waſte is greater in the tinging drops of the outer rainbow on account of the double reflection, than in the drops of the inner. The opacity of the ſpace behind the tinging drops is alſo the cauſe of the briſkneſs of the colours in thoſe rainbows produced on the water changed to vapour and forced high either out of a fountain, or out of a ſquirt, or in a fall of water.

§. 394. Above the upper and ſecond rainbow appears at ſome times a third, on the drops of rain, which are above the tinging drops of the upper, having the poſition, that the incident rays of the ſun come to the eye after a double refraction and a triple reflection. A remarkable inſtance to this purpoſe we have related in the general hiſtory of voyages by Don *Antonio de Ulloa*, T. 9. ſect. 1. l. 6. c. 9. As *de Ulloa* was with the *French* academicians on the high and deſart mountain *Pambamarca* in the kingdom of *Quito*; each of them ſaw his own image over againſt the ſide on which the ſun roſe, as in a mirrour, and the head of each image incompaſſed with three rainbows, having all of them one and the ſame centre. The laſt or outmoſt colours of the one rainbow touched the firſt of the following. And externally round all the three circles, but at ſome diſtance from them, a fourth bow appeared, which ſhewed white only.

When

When one of the ſpectators moved from one ſide to the other; the whole appearance followed him in a like form and order. And though they were between ſix and ſeven in number and ſtood quite cloſe together, yet each could only ſee his own image, but not the appearance too of the reſt. As the figure of their bodies was pourtraied in the middle ſpace of the incompaſſing rainbow, the vapours of this ſpace muſt have been in the ſtate, for the incident and reflected rays to form equal angles (§. 150.)

§. 395. If the line O F fig. 2. plate VI. is conceived to be produced from the eye backward to the ſun, it at laſt paſſes through his centre. For, O F runs parallel with the rays incident on the drops of rain; and the ſpace between them and the line O F is to be deemed a point in compariſon with the ſpace of the ſun. If O F is conceived to be carried forwards from the eye to the ſurface of rain, it at laſt paſſes through the centre of the circle, in whoſe circumference the rainbow appears. For, the tinging rays form about this line a circle (§. 390.)

§. 396. Stand the ſun at the horizon, and the ſpectator on the earth's ſurface, the appearing rainbow exhibits the circumference of a ſemicircle. Suppoſe the eye of the ſpectator in O, fig. 3. plate VI. the one point of the horizon, where the ſun is ſeen, in H; and the other point of the horizon, above which the ſurface of rain ſtands, in R. The right line, which may be drawn from H through O to R, is called the apparent horizontal line. On this

this falls the line O F, as it goes through the centre of the ſun, which is ſeen at the horizon in H. But O F at the ſame time goes through the centre of the circle, in whoſe circumference the rainbow is exhibited (§. 395.) And therefore alſo the centre of this circle falls on the horizontal line H R. Through this centre the diameter of the circle, in whoſe circumference is the rainbow, is divided into two equal parts; the one of which is above, the other beneath the horizon. Under theſe circumſtances the rainbow muſt appear in the form of a ſemicircle. And then the height of the rainbow is either 44° 2′, or 54° 5′ (§. 389 and 391.)

§. 397. Did therefore the earth admit the circular ſurface, through whoſe centre the line O F may be drawn, to be as well fully enlightened by the ſun, as plainly ſeen by the eye in O; the rainbow would appear as a whole circumference of a circle in the falling drops of this circular ſurface.

§. 398. If the ſun is above the horizon in S, fig. 3. plate VI. and the eye in O on the earth's ſurface; the appearing rainbow muſt be leſs than the circumference of a ſemicircle. For then, the line *s* O F, drawn through the ſun S and eye O, goes through the horizontal line H R, and forms with it an oblique angle R O F (§. 395.) to which the angle *s* O H is the verticle angle. Now as vertical angles, which have a common point, are mutually equal; the rainbow wants of its ſemicircle ſo much,

as the height of the ſun above the horizon has increaſed.

§. 399. Were therefore the height of the ſun above the horizon, or the angle ♋ O H 42° 2′; the eye on the earth's ſurface would only view the extremity of the ordinary rainbow at the horizon in R. For the line ♋ O *f* would not only go through the horizontal line H R, but alſo form with it an angle R O *f* of 42° 2′.

§. 400. When the ordinary rainbow exhibits the form of a ſemicircle; its higheſt point is in C, and the ray C O, falling out of C into the eye, forms with the horizon O R an angle of 42° 2′. Were therefore the earth no obſtacle to the rays of the ſun, and to the falling drops; the extremity of the other ſemicircle of the ordinary rainbow would be under the horizon in *c*. For, the angle C O R is equal to the angle R O *c*. Were the ſun in S, the extremity of the ordinary rainbow would extend under the horizon quite to *c c*. For, the angle E O F = the angle F O *c c*. Were the ſun in ♋, the extremity of the ordinary rainbow would be under the horizon in *c c c*. For the angle R O *c* = the angle *c* O *c c c*.

§. 401. The ſun being higher than 42° 2′ above the horizon, the ſpectator, when on the earth's ſurface, can obſerve no ordinary rainbow; for, he can only ſee the extremity of the ordinary rainbow, when the height of the ſun is accurately 40° 2′

(§. 399.)

(§. 399.) In like manner none of the upper rainbow can be diſtinguiſhed on the earth's ſurface, when the height of the ſun exceeds 54° 7′. And hence with us in *Germany* no rainbow can be ſeen in ſummer a while before, and after noon. For about this time the height of the ſun prevents the rainbow from being perceived by the eye.

§. 402. Was the ſpectator placed on ſuch a height, that he ſaw the ſun under the horizontal line, which may be drawn on the level; he might obſerve more of an appearing rainbow than the half periphery of a circle. For, as the rainbow is leſs than a ſemicircle, when the ſun is ſomewhat raiſed above the apparent horizontal line (§. 398.); it muſt on the contrary be greater than a ſemicircle, when the ſun would be ſeen under the apparent horizontal line, which may be drawn on the level of the earth.

§. 403. The more diſtant the ſurface of rain from the eye of the ſpectator, the greater are the degrees that conſtitute the variegated bow. Whereas the nigher the ſurface of rain is to the viewing eye, the ſmaller are theſe degrees. For, the circular ſurface, a part of whoſe circumference the rainbow occupies, may be conſidered as the baſe of a cone, and O F as its axis (§. 390.) fig. 3. plate VI. Now the longer the axis of a cone, the greater are the degrees, which form the periphery of the conical ſurface. And the ſhorter the axis, the ſmaller are the degrees of this periphery.

§. 404. Sometimes a part is wanting to the full rainbow, which may be ſeen above the horizon; for inſtance, the upper convexity, or a leg. This is occaſioned by a defect of the tinging drops in theſe places. At other times the legs of a rainbow appear to ſtand on the graſs and herbs; which happens, when the drops lying on the graſs and herbs ſo refract the incident rays of the ſun, as to form with the line O F, fig. 2. plate VI. the angles neceſſary in the rainbow. When the ſpectator would approach the rainbow, it gives way before him. Whereas if the ſpectator leave the rainbow, it follows him; for, as ſoon as the ſpectator ſhifts place, ſo ſoon the refracted rays come out of other drops to his eye.

CHAP. VI.

Of the GENERATION of THUNDER and LIGHTENING.

§. 405. THAT the vapours of the atmoſphere partake of ſaline and ſulphureous matters is well known; and that the mixture and accenſion of theſe produce a clap or an exploſion. This gunpowder in ſome meaſure explains, in the compoſition of which ſulphur, ſalt-petre and wood-coals are joined together; alſo the *pulvis fulminans*, which is prepared of ſalt-petre, ſulphur and ſalt of tartar; and the *aurum fulminans*, which is made from leaf-gold, diſſolved in *aqua regia*, and precipitated either with the aqueous ſpirit of

ſal

ſal ammoniack, or with oil of tartar *per deliquium*, or with both, on dropping them in alternately. Hence it appears, thunder may be explained from the mixing and firing ſalts and ſulphureous matters in the atmoſphere.

§. 406. The query only is, how the ſulphureous matters are fired in the air? According to *Lemery*, a paſte made of iron filings and ſtamped ſulphur and water, gradually takes fire. But whether ſo many particles of iron float in the air, as to heat with the ſulphureous matters, is a thing not hitherto made out. At times too, certain matters take fire on the earth without any particles of iron; for inſtance, moiſt hay: and ſo we are to conſider the cloſeneſs and weight with which ſuch matters lie on each other, and the upper preſs on the under. In the atmoſphere no ſuch piling up together of matters, is to be imagined.

§. 407. Trees, men and houſes are often ſtruck by lightening without taking fire. In theſe flaſhes of lightening there may be very little ſulphur. Was ſuch a flaſh, a ſtream of kindled ſulphur, how could inflammable matters remain unkindled on its touch? Such flaſhes of lightening are called *cold claps*. We are not to conclude that, on the ſcore of their great velocity, they could not fire. For, hitherto it has not appeared from any one inſtance, that the kindling flaſhes, which we may call *hot claps*, move with leſs velocity than the cold. From the cold claps therefore it appears, that there are flaſhes of lightening, holding either quite none

or very little fired ſulphur. And thus in order to explain the phenomena of thunder and lightening, we are to ſeek for other cauſes than thoſe hitherto adduced.

§. 408. When thunder and lightening are generated, electrical effects are obſerved at the ſame time in the ſame parts of the atmoſphere. Hang at the time of a thunder-ſtorm a metal rod in the free air; or let a man ſtand on a cake of pitch, or on a ſilken net; leaf-gold, held either under the rod, or under the hand of the man, fall into friſking motions. If one approach a finger, or a metal to the rod or to the man; electrical ſparks are made to burſt forth, which are now weak, again ſtrong, according as the matter of the thunder is diſtant or nearer, or itſelf weak or ſtrong. All the effects, which human art has hitherto diſcovered by machines in electrifying, manifeſt themſelves in thunder-ſtorms, when chains or rods hanging by ſilk are touched by the air of the ſtorm, without being obliged to excite the electricity by art. The firſt obſervations were made in *France* in 1752. The abbé *Nollet* recounts them in his *Lettres ſur l'electricite.* Mr. *Benjamin Franklin* in the letters he wrote in 1747, 1748, and 1749 from *Philadelphia* to Mr. *Collinſon* in *London*, and particularly by the hint in the fourth letter, how to diſcover by trial whether the matter of electricity and the matter of thunder were really one and the ſame, gave occaſion to theſe obſervations. Now what had been obſerved of the electricity of thunder in 1752 in *France*, was confirmed in other

countries

countries besides by different trials, which M. *Mylius* has described in the *Physical amusements*, P. 17. After professor *Richman* had been killed by a flash of lightening in observing at *Petersburg* on *August* 6, 1753, the electrical force in thunder and lightening, I caused to be made an instrument, by which the electrical effects of thunder may be observed at a distance without danger, and I described it in the *Programma de avertendi fulminis artificio ex doctrina electricitatis*, p. 17, 18. and represented it in fig. 2. and 3.

§. 409. As thus experience assures us, that in thunder-storms the electrical matter of the atmosphere is in motion; the enquiry is, whether this motion be produced by rubbing, or by setting on fire the sulphureous and oleaginous matters of the air? Under the first of these hypotheses, we might consider the firing of these matters with the other appearances and effects of thunder and lightening as bare effects of the electrical force of the atmosphere. For, if we consider, that an intense electrical spark and flash bursts forth with a snap (§. 315.) and fires not only spirit of wine, but seed of *lycopodium*, and dissolves *aurum fulminans* (§. 238. seq.) and in like manner strikes holes in paper, leather, parchment, and thin plates of tin; the experiments to this purpose I alledged l. c. p. 14, 15. It is easy to conceive, that it depends only on the quantity and density of the electrical matter in the air, to fire either the sulphureous and inflammable matters in the air, or in animals, plants and buildings,

and to melt and break in pieces metals and other hard bodies.

§. 410. Experience and experiment have taught us, that heat and fire excite no electricity, when a body, which may be electrified by rubbing, is not rubbed. Whence we have reason to maintain, that thunder and lightening arise, by the mutual friction of what is contained in the air, against each other, whereby the electrical matter contained in them is put into an intense motion. Several circumstances, which have been remarked in the electricity of thunder, serve to confirm this observation. If a metal bar, hanging either by silken strings, or resting on pitch, is touched by the air of a thunderstorm; its electricity appears not in one and the same degree of intenseness. In some time before the lightening the electrical effects are quite weak; but they gradually turn more intense. And when the sparks are at the strongest, the lightening arises in the air: but with it also the electricity vanishes. Then again it begins gradually to increase, till again at last with the following lightening it gain the highest pitch.

§. 411. And here two queries are to be answered: First, how is it possible the electrical force should collect itself in a cloud, or in a certain quarter of the atmosphere? Secondly, whence should arise the great power of the electrical force in the air? In artificial electrifying, for the communicated electricity to be considerable in a body, it must rest on a body electrical of itself, that is, such a body, whose electrical

trical matter is in no remarkable manner resolved and expanded by the bare contact of an expansive electrical matter (§ 234, 246.) Among these bodies ranks pure air. For, an electrified bit of leaf-gold may be driven about for a considerable time in the air from one place to another, so you pursue it with a rubbed glass tube, by which the electricity was at first communicated to it, without being able to touch it therewith. From this it is clear, that the electricity communicated to the bit of gold lasts for a long time in the air (§. 252); and consequently the air, considering that the communicated electricity ceases not so soon in it by its contact, belongs to the bodies electrical of themselves. If therefore a cloud, to whose matters the electricity may be communicated from others, that mutually rub, is environed quite round with air, in which no vapours are contained, that may be electrified without rubbing: it is in the state, that the electrical force may be collected in it, or so excited, as to last a long time.

§. 412. Water is rich in electrical matter, which manifests itself by strong effects, when sufficiently resolved by the original electricity. In particular, the electrical virtue of water is heightened, when mixed with saltpetre, potash or other salts. The intenser therefore the original electricity, excited in a certain quarter of the air by the attrition of sulphureous and other matters, acts on a water-cloud environed with pure air; and the richer it is in

water

water and ſaline matters, the greater will be the electrical power of ſuch a thunder-cloud.

§. 413. The electrical ſparks and flaſhes are produced, when an unelectrified body is ſo nigh one electrified, that the electrical matters of both alternately inſinuate into each other, and collect themſelves between them. And thus a body is touched by a thunder-flaſh, when a quantity of electrified vapours of the air come ſo to ſtand againſt it, that its own electrical matter by its elaſticity (§. 244.) inſinuates plentifully into them. The quickneſs and violence of the thunder-flaſh ariſes hence, that the electrical matters of the vapours are reſolved exceedingly ſubtle, and expand themſelves very wide. For, in this manner, the electrical matter of the body, which is neareſt theſe vapours, finds a ſpace, in which it may expand almoſt without obſtruction, and thus at once goes with all its might againſt the vapours. And therefore by the mixture of electrical matters, which ſtream out of the vapours, and the bodies next to them, inſtantly a flaſh and ſnap ariſe. The longer and larger the ſpace, through which both electrical matters plentifully expand themſelves, the longer and thicker is the thunder-flaſh. How by art to imitate this, I have explained in the cited *Programma*, p. 10--12.

§. 414. If the quarter, in which the thunder-flaſh is produced, is impregnated with many particles of ſulphur, and the power of the flaſh very great, the ſulphur is fired by it. And even this happens,

ıappens, when in a building it meets with matters, hat may be eaſily fired. The firing the ſeeds of *ycopodium* on a metal is an inſtance, when metal nd ſeeds are touched by an electrical flaſh, excited y art. If the electrical matter of a thunder-flaſh ıas little ſulphur in it, and on the contrary is mixt ıp with matters, that prevent the firing; ſuch a laſh paſſes through catching or inflammable things, vithout ſetting them on fire. Yet notwithſtanding, ıch a cold flaſh may by the violence of the electrical natter pierce through, and break in pieces firm odies, and melt glaſs and metals.

§. 415. If an electrified body is ſo diſtant from ne unelectrified, that, though the electrical matters f both bodies act on each other, yet they cannot ollect themſelves between them into any denſe cy-inder; on the ſurfaces of both bodies there ariſes a ight only, which ſtreams forth in diverging lines vith a whizzing noiſe when the parts, at which the ight comes forth, run to a point (§ 237.) Such a ight and flaſhes will ariſe on iron bars on buildings ıt the time of a thunder-ſtorm, when the thunder-louds are at ſuch a diſtance from the iron bars, hat the electrical matters ſtream out of the bars ınd clouds againſt each other, but theſe ſtream-ng matters can touch each other with their ends nly. An inſtance to this purpoſe profeſſor *Kaſtner* gives in the *Hamburg* magazine, T. 9. p. 359. from he *Utrecht French* gazette of the year 1752. On he ſteeple of the church at *Plauzat* in *Auvergne* is an

an iron crofs without paint or varnifh. The ends of this crofs, the bars of which project about two feet, are not rounded, but formed almoft like the *French* lilies with fharp points. As often as any great ftorm, accompanied with thick clouds and repeated lightenings happens; at each of the extremities of this crofs a luminous body appears. By a tradition immemorial it very rarely happens, that the thunder breaks in at *Plauzat*, or thereabouts, when this appearance fhews or will fhew itfelf. So foon as it has appeared, all fear vanifhes. The three mentioned lights have colours like the rainbow. Their ground, or under part, is round, and at the upper ends they run tapering like cones. Many times they laft for 2½ hours, and ftand out the rain, fall it never fo heavy. This is confirmed by all the inhabitants of *Plauzat*, and by a letter of the parifh prieft M. *Binon*, who lived there for 27 years, and is an accurate obferver. A like light, on *February* 2, 1749, juft after fix in the evening, was obferved on the fteeple of St. *Peter*. This profeffor *Kaftner* relates from the account he had fent him by parfon *Leffer* in *Nordhaufen*, in the *Hamburg* magazine, T. 7. p. 420. In a high ftorm of wind, which came more from the north than weft, with much fnow and hail, on the fteeple the upper points of the iron, on which the mufick-piece for founding was placed, had all of them a bright flame. But one of them which ftands at the corner to the fouth at the knee, where it is bent, had a flame, as alfo two flames above

bove on the ſcrew. Both theſe flames were extinguiſhed ſeveral times with a finger, but began again irectly to ſhine, on removing the hand that xtinguiſhed them. This light had not the leaſt egree of heat. If one went into the wind againſt his iron, it forbore to ſhine, and that ſo long, till he perſon moved out of the wind again; when it ave forth its light again directly. The ſhining of he ſaid iron laſted for a quarter of an hour. The ght appeared of a quite pale colour, in which ſomehat bluiſh appeared towards the iron. The height f the flame was 1 ½ inch, and the breadth ½ inch. he flame waved not with the wind, but ſtood at ne time as at another. The light made ſuch a oiſe, as when a ſmall fly hangs and buzzes in a ider's web. This buzzing was heard in 1747 in road day-light. The iron alſo, that exhibited the ree flames, ſhone bright in the night in a great orm of thunder and lightening. To both theſe ſtances I ſhall beg leave to add one more, comunicated to me by M. *Schwartz* in 1754, as he d it from people of underſtanding and credit. It ppened on a tower of a caſtle belonging to the mily of *Kreibitz*. The caſtle lies about two hours om *Naumburg* on a high mountain, at the foot of hich in a deep valley the *Saal* runs by, and it has o towers, one of which ſtands neareſt the aſcent the mountain and the water running by below. To is tower the inhabitants of the place have for a long ne back been attentive, when a thunder-ſtorm has gathered;

gathered; as at that time a flame, in form of one of the largeſt ſtars, has appeared over the knob or ball of the tower, which on the approach of the ſtorm ever turned bigger, and on the diſtance or decreaſe thereof, like a lamp, whoſe oil begins to fail, has gradually decreaſed. And here the report goes, that formerly on ſeeing this flame no thunder-clap was apprehended, and that the oldeſt perſons living could not remember, that the ſtorm had ever fallen on this eſtate. A few years ago the owner took down the old knob of the ſaid tower, and mended it, as having been ſhot through by a ball, after raiſing the tower ſix feet high. The evening following a thunder-ſtorm aroſe, and beat into the tower, and broke to pieces the wall and three pillars. But above the knob there was then no flame obſerved. Now as the ſtorm ſince that time has fallen five times on this eſtate, yet without firing, though the light had appeared above the knob of the tower, without having been extinguiſhed by heavieſt rains; ſo at preſent people are full of apprehenſions for what they otherwiſe were wont to rejoice at; as commonly, when the ſtorm approaches to the tower on a certain ſide, which cannot yet be ſufficiently determined and aſſigned, a violent clap and flaſh, yet without firing, ariſe.

CHAP.

CHAP. VII.

Of the Height of the VAPOURS.

§. 416. THE rarity of the air is always proportioned to its diſtance from the earth (§. 115.) And at a certain height muſt be ſo rare, as to be unable to bear any more vapours, in which the rays of the ſun may be refracted and reflected, whereby the twilight ariſes (§. 386.)

§. 417. Suppoſe the particle of the atmoſphere, which at the beginning of the morning and end of the evening twilight reflects the impinging rays of the ſun, to be at A, fig. 3. plate XI. And thus its diſtance from the earth's ſurface is the line A L, and from the centre of the earth the line A C, which conſiſts of the line A L and the line L C. The line L C is the earth's ſemidiameter. Could we therefore find the line A C, we might find the line A L, the diſtance or height of the reflecting particle of air from and above the earth's ſurface, on deducting L C from A C.

§. 418. The ray of light E D A, which comes from the ſun under the horizon into the atmoſphere, forms at D, where it touches the earth's ſurface, with the line D C, the ſemidiameter of the earth, a right angle, *Wolfius*'s *Geometriæ Elementa*, §. 309. Were therefore in the triangle D A C the angle at A known, the line A C might be found by the following

ing proportion. As the ſine of the angle at A is to the earth's ſemidiameter D C, ſo is the ſine of the right angle at D to the line A C.

§. 419. The angle D A C might be found, were the angle at C known. For, the angle at D is a right angle, or = 90°, and conſequently already known. If the ſum of two known angles is deducted from 180, the ſum of all the three angles of a triangle, there remains the third angle.

§. 420. The reflected ray, which touches the earth's ſurface at O, forms at O with the line O C, the earth's ſemidiameter, a right angle. The lines D C and O C are mutually equal, as being ſemidiameters of the earth, and the line A C is common to both triangles A C D and A C O. And therefore the angle D A C is equal to the angle O A C, and the angle D C A equal to the angle O C A. For, when in two ſimilar triangles A D C and A O C the ſide D C = O C, and the ſide A C = A C, and the angle D equal to the angle O, both oppoſite to ſuch a ſide A C; ſo alſo is the angle D A C = O A C, and D C A = O C A, *Wolfius*'s *Elementa Geom.* (§. 235.)

§. 421. Both theſe angles D C A and O C A, taken together, are equal to the angle I A E, which the lines I A and E A form at A. For, the angle I A E with the two angles D A C and O A C makes two right angles, as they have a ſemicircle for their meaſure. The two angles D C A and O C A with the two angles D A C and O A C alſo make

two

two right angles. But the ſum of the ſix angles in two triangles is equal to four right angles. And thus the ſum of the angles I A E + D A C and O A C = the ſum of the angles D C A and O C A + D A C and O A C. And deducting one and the ſame quantity from two equal quantities, as here D A C and O A C, there remain equal quantities. And conſequently both the angles D C A and O C A taken together are equal to the angle I A E.

§. 422. Now as the angle D C A is equal to the angle O C A (§. 420); ſo is the angle D C A = $\frac{1}{2}$ I A E. If therefore I A E were = 17° 28′, D E A would be = 8° 44′.

§. 423. The angle I A E is the meaſure of the ſun's depreſſion under the horizon. Properly indeed the ang'e at O, which is formed by the line I O, and the line, that may be drawn from O to the ſun S, is the meaſure of the depreſſion of the ſun under the horizon. But as the line A O, in regard of the great diſtance of the ſun from the earth, goes for nothing, we may inſtead of the angle at O take that at A, which is formed by I A and E A. When the ſun ſtands at the horizon, his rays run parallel with it. If ſomewhat under the horizon, he forms with the apparent horizon I O at A an acute angle. And come he to be more depreſſed under the horizon, the angle at A will be leſs acute, and conſequently greater. And thus the depreſſion of the ſun under the horizon may be meaſured by ſuch an angle.

§. 424. The angle I A E at the end of the evening and beginning of the morning twilight is 17° 28'. For, in both these times the depression of the sun under the horizon is about 18° (§. 386.) But the ray of the sun E A at the horizon undergoes a refraction of 32' (§. 187.) so that deducting 32' from 18°, there remain for the angle I A E 17° 28'.

§. 425. And if thus the angle D C A, half of the angle I A E, is = 8° 44' (§. 422.) the angle D A C is = 81° 16', on deducting the sum of the right angle at D, and of the angle D C A, that is, 98° 44', from 180°, the sum of all the three angles in the triangle A D C (§. 419.)

§. 426. The line A C, the distance of the particles of vapour, which at the end of the evening and beginning of the morning twilight reflect the rays to the eye, is therefore 870 *German* miles. For, the logarithm of the sine of the angle D A C is = 99949352, the logarithm of the line D C = 29344984, and the logarithm of the sine of the right angle at D = 100000000. And thus (§. 418.) the logarithm of the line A C = 29395632. The calculation is as follows:

Log. sine	D A C	=	99949352
	D C	=	29344984
Sine total		=	100000000
	A C	=	29395632

This logarithm gives 870.

§. 427. If therefore 860 miles, the earth's ſemidiameter, be deducted therefrom, A L, the height of the reflecting vapours, conſiſts of 10 *German* miles *.

SECT. IV.

Of animated Bodies.

§. 428. ANIMATED bodies conſiſt of ſolid and fluid parts; the firſt in general are adapted, by means of their make and configuration, to produce peculiar actions; and ſome in particular ſo fitted for the purpoſe, as by the fluid parts moving through them, inceſſantly again to recruit or replace the waſte of the matters, of which the ſolids conſiſt. Theſe ſolid parts are in general called *organs* and *inſtruments*; and their configuration and diſpoſition, *organiſm*.

§. 429. In ſome animated bodies there appear to be ſpontaneous motions; in others, none. The bodies of the laſt ſpecies are called vegetables, or plants; of the firſt, animal.

* A common *German* mile is to a common *Engliſh* mile, a little better than as 3 to 1.

MEMBER I.

Of the Motions of animated Bodies.

CHAP. I.

Of the Sap, and of its Motion in Vegetables or Plants.

§. 430. IN vegetables or plants are three ſorts of veſſels, containing fluids; viz. ſmall holes or orifices in the ſkins or rinds, and then tubes, and veſicles. Into the ſmall holes of the ſkins inſinuates the moiſture, coming either from without on the plants, or riſing out of the plants into the air. Some tubes are filled with air, others with a juice or ſap: as both may be ſeen in the vine and mulberry-tree with the naked eyes, but in other vegetables by magnifying glaſſes. The veſicles, which belong to the ſoft matter of a plant, are in like manner filled with a ſap. So in the thin ſlices of the rind of a lemon magnifying glaſſes ſhew the ſap, which gives it its odour.

§. 431. The ſap in the tubes and veſicles ariſes from the moiſture, which from without inſinuates into the ſmall holes or orifices of the rind, and chiefly out of the earth into the root, (as the undermoſt part

part of the plant, ſticking in the earth) and ſaturated with earthy and oleaginous matters. This moiſture goes into the ſap-ducts, which we may repreſent to ourſelves as ſo many capillary tubes (§. 54.) turning ever gradually finer, the nearer they come to the branches and boughs and top of the plant. From the outmoſt extremities of theſe capillary tubes different parts of the ſap inſinuate into the ſmall orifices of the rind, and out of theſe into the air. This is called the *tranſpiration.* The matters remaining behind give the plants an expanſion in length, breadth and thickneſs, which is called their *growth.*

§. 432. As the ſap cannot ſo eaſily and readily come out of the veſicles, as it is propagated thro' the capillaries; ſo the different matters of the ſap may by the heat be more ſubtly reſolved and mixed together in the veſicles, than in the ſaid capillaries. We are therefore to conſider the veſicles as the principal organs, in which the parts of the ſap are ſo changed, that from it a mixt matter ariſes, adapted to the ſpecies and nature of the plant, wherein the preparation happens. We have reaſon to aſcribe to the force of a plant ſuch an elaboration and change of the ſap; as plants of different ſpecies live, grow and bring forth fruit in one and the ſame ſoil: if an apricock ſlip is engrafted in a plum-tree, it notwithſtanding bears apricocks, though plums grow on the branches of the plum-tree. And the fluid matter, which the plum-tree takes by its root, and im-

parts to the apricock ſlip, muſt be differently prepared in this laſt, from what it is in the plum-tree.

§. 433. The aſcent of the ſap into the root is much quicker, than is the tranſpiration from the ſurface of the tree and its leaves. And this ſurface is larger by far than the ſurface of the root. Roſe therefore the ſap into the root not quicker than it tranſpires from the other parts of the plant; the plant would ſoon come to decay for want of ſap. Dr. Hales cutting horizontally acroſs the ſtem of a ſun-flower, which in a hot day had loſt by tranſpiration 30 ounces of its weight, found the ſection to meaſure a ſquare inch: whereas the ſurface of the leaves contained 5616 ſquare inches; ſo that the ſap muſt have moved 5616 times quicker through the ſtem, than it was emitted from the leaves into the air.

§. 434. The ſap-ducts muſt be therefore extremely narrow. For, the narrower a capillary tube, the quicker riſes the liquid therein.

CHAP. II.

Of the Blood and its Motion.

§. 435. ANIMAL bodies are of two ſorts; ſome conſiſt of a ſtructure of hard and organical parts, or bones, which are cloathed with a ſoft matter or fleſh: but in others no bones are to be found. The animal bodies without bones are called *inſects*, while certain ſingle parts, which ſtand mutu-

ally

ally connected together, appear to be separated asunder by certain insections, indentures, or incisions.

§. 436. The fluid matter, by whose motion animal bodies live, is the blood; which chiefly, in the bodies furnished with bones, consists of two parts, a water or serum, and red globules, distinguishable by the magnifying glass.

§. 437. The vessels, in which the blood is contained and circulated, are the heart, and certain tubes connected therewith; some of which receive the blood from the heart, others again carry it back thither. The first are called *arteries*; the second, *veins*. The heart consists of two cavities or receptacles, called *ventricles*, which are parted asunder by a partition or *septum*. Both cavities take in blood, on dilating themselves; and both expel the blood, on contracting themselves. In the time, that one cavity by the contraction or systole drives the blood into an artery, it can admit no blood from the vein. There are therefore certain antereceptacles called *auricles*, in which the blood, coming from the veins, is collected, till the ventricle of the heart again dilates, or is in a state of diastole. The right ventricle of the heart has its blood from the *vena cava*, and conveys it into the pulmonary artery. From this last it goes into the pulmonary vein, which conveys it to the left ventricle of the heart. From this again it is squirted into the great artery or *aorta*, which divides itself into two

branches; one of which carries the blood to the head, the other to the under parts of the body. From both branches arife other fmaller, continually fubdivided into others ftill lefs. From thefe fmaller arteries the blood comes into fmall ramifications of the veins, and from thefe into ftill bigger veins, till it is again carried by the large *vena cava* into the right ventricle of the heart.

§. 438. This running round, or circulation of the blood, in which it is carried from the heart to the arteries, and from thefe again to the veins, and from the veins back again to the heart, may be difcovered partly by magnifying glaffes in the tail of a fmall fifh; partly by the following experiments. If an artery is tied, it fwells towards the heart, and collapfes at the other end; but a vein thus tied, falls together or collapfes towards the heart, and fwells towards the extremities.

§. 439. To the motion of the blood refpiration is neceffary; which is performed by means of the lungs, which confift of perfectly fmall vefícles, into which the air, by virtue of its elafticity, forces thro' a tube, on the breaft's dilating itfelf; and is expelled out of the vefícles of the lungs through the wind-pipe or *trachea*, on the breaft's contracting itfelf. The thing itfelf may be diftinctly fhewn by means of the lung-machine.

§. 440. Though the eye diftinguifhes chiefly in the blood a ferum and red globules only, yet the feveral fpecies of matters, to be found in the whole body,

body, are mixed together in it. For, from the blood, every thing in an animal body muſt take its riſe. But the ſeveral ſecretions happen after that the blood is come to the ſmalleſt tubes: and thus in the brain the nervous juice is ſecreted; in the glands of the ſtomach, the gaſtrick liquor; in the liver, the gall; in the meſentery, a juice denominated from it; in the kidneys, the urine; in the teſticles, the ſperma, or ſeed.

§. 441. The blood is formed from the meat and drink we take in, by the following operations. After that the meat and drink are, by the heat of the ſtomach, and its peculiar liquor, and the preſſure, which reſpiration gives it, ſufficiently reſolved and mixed together; they are forced into the *duodenum*, and there mixed with the gall and pancreatick juice, and thereby thinned or diluted; and then this mixture is called the *chyle*, or nutritious juice. It inſinuates into the lacteals, which are uncommonly narrow. From the lacteals the *chyle* goes along the meſentery into the *receptaculum chyli*; out of this, into the thoracick duct, and from this into the ſubclavian vein, and out of this laſt into the *vena cava*, which conveys it into the right ventricle of the heart.

CHAP.

CHAP. III.

Of Animal Motion.

§. 442. THE instruments, by which the motions in an animal body are performed, are called *muſcles*; and conſiſt of three principal parts, viz. the head, tail and belly. The head is the one end, towards which the motion happens; and the tail, the other, and moveable end. Head and tail are called tendons, when faſtened to bones. The belly is the middle part of the muſcle, and conſiſts of carneous fibres, diſpoſed lengthwiſe, and croſſed by others far more ſubtle. In theſe three parts are, beſides, veins, nerves and veſſels, which contain a certain kind of juice. That the muſcles are the organs of motion, appears hence; that a limb becomes unfit for motion, on tying or cutting its muſcle.

§. 443. But the muſcle, in order to perform its motion, muſt have the carneous fibres of the belly ſhortened, and conſequently ſwelled. For, hereby the moveable end of the muſcle moves towards its head. To the cauſes, whereby the belly of the muſcle ſwells, in all probability, the nervous juice is to be reckoned. For, a muſcle is unfit for motion, on making a ligature on the nerve going to it, and thus hindering the influx of the nervous juice. But how by its influx, the belly of a muſcle may be ſwelled? different opinions have ariſen, ſome maintaining, that the carneous fibres are ſhortened, in the

manner

manner of a moiſtened rope, by the inſinuating nervous fluid, as being diſtended in breadth: others imagining the blood-veſſels to be compreſſed by the nervous juice, and thus the muſcles, on account of the blood reſtrained, neceſſarily to ſwell: others again, being of the opinion, that the blood and nervous juice are mixed together, and that hereby an effervеſcence ariſes, whereby the ſmall cavities between the carneous fibres are diſtended, and conſequently forced aſunder. M. *Dan. Bernouilli* publiſhed in the *Comment. Petropolit.* T. I. A *tentamen novæ de motu muſculorum theoriæ*; in which the ſwelling and ſhortening of the muſcles is explained in a very intelligible manner. A fleſhy longitudinal fibre conſiſts of fibrils, which form a hollow cylinder. Repreſent we to ourſelves, fig. 5. plate VI. a number of ſuch fibrils, which indeed admit not eaſily being lengthened, but yet their coheſion is ſo ſmall, that the outmoſt *a c* and *b d* may be eaſily removed aſunder. Let thoſe fibrils, which are now expanded on an even ſurface, be ſo rolled up together, that *a c* and *b d* ſhall mutually touch, and form a hollow cylinder. And in this manner there ariſes a fleſhy longitudinal fibre, ſuch as is repreſented fig. 6. plate VI. The cavity of ſuch a fleſhy fibre is conſtantly filled with blood. For, not only a branch of an artery goes to each muſcle, but the muſcle alſo has a certain degree of redneſs, which vaniſhes, on forcing lukewarm water into a muſcle through its artery. In the tendons the fibres lie cloſer together,

gether, and consequently admit of no blood into their cavities; and hence they appear white. The cross or transverse fibres, by which the longitudinal fibres are bound down, are parted asunder by certain interstices, and represented fig. 5. by the lines *e f*, *g h*, &c. and in fig. 6. by the circles E F, H G, &c. By these circular transverse fibres the cavity of an entire longitudinal fibre is divided into several areas or spaces; such as the space E F G H, between both the transverse fibres E F and G H. These cross fibres may be nothing but pure slips of nerves, as being tough and hard, nor easily admitting the being once tore asunder with a needle.

Now in order to shew, how a small influx of the nervous juice is capable of making the cylindrical spaces, into which the cavity of a longitudinal fibre is divided, to expand in breadth, and become bellied: you may represent to yourself the space EFGH, which is expressed in fig. 6. under the form of a cylinder apart, fig. 7. Let its base be E F M, or H G N, and its height or length E H, or M N or F G. On drawing the annular fibrils E M F and H N G somewhat together, so as to assume the oblong figure *e m f* and *h n g*, fig. 8. the cylindrical figure of the space E F H G, fig. 7. will be raised and bellied, fig. 8. The fibres *e p h*, *m n*, and the others retain their former length, as they admit not easily of being lengthened. The internal capacity of the space or area remains also the same; as being filled with blood, which can neither be expelled, nor,

nor, in the manner of the air, reduced into a narrower ſpace. The length of the ſpace M N is ſhortened, ſo the annular fibrils E M F and H N G do in their contraction, whereby they acquire the figures *e m f* and *h n g*, act againſt each other. But ſo the length of the ſpace is ſhortened, its middle will be widened; ſo that P Q expands to *p q*. This ſwelling is by ſo much the eaſier, the weaker is the coheſion of the fleſhy fibres among themſelves. That the annular fibrils may be contracted by the influx of the nervous juice, appears hence; that the cavities of the annular fibrils are uncommonly ſmall, and thus may be eaſily filled by the nervous juice. For, though it be highly ſubtle, it muſt however occupy a certain ſpace. And that it actually flows into the annular fibrils, is in particular confirmed hereby, that as was mentioned above, they are ſlips deriving from nerves, and conſequently allow a free ingreſs to the nervous juice.

For the ſwelled muſcle to ceaſe acting, and therefore to ſink down or collapſe again; the nervous juice muſt return back from the annular fibrils. Should it be ſuppoſed to evaporate in them, we can ſee no poſſibility, whence a conſtant freſh ſupply of nervous juice could be generated in ſo large a quantity, as is however neceſſary. The heart daily contracts above a hundred thouſand times. How large a quantity therefore of nervous juice muſt be ſeparated daily from the meat and drink taken in, did, at each contraction of the heart, the

influent nervous juice diffuſe itſelf fully through the fibrils, and were thus, at each following contraction, a new influx in equal meaſure required! Let us reckon to a ſingle contraction only the thouſandth part of a grain. How rich in this juice muſt the aliments be, which a man takes in a day! The force, whereby the influent nervous juice is repelled, is the elaſticity of the annular fibrils. The cauſe, which forces it into them, is indeed unknown. But be it of what nature it will; ſo much however is clear, that a muſcle muſt continue in its ſtate of contraction, and remain ſo long ſwelled, as the action of the cauſe, which impels the nervous juice into the tranſverſe fibrils, and *their* reaction, which ariſes from their elaſticity, are mutually equal.

As the ſpaces or areas of the muſcle ſwell by the blood contained in them, when their length is ſhortened: we hence learn, how it comes, that the motion of the muſcle ceaſes, on making a ligature on its artery. For, as the blood-veſſels conſtantly carry the blood from and to the heart; ſo the ſpaces are emptied of blood, and have no freſh ſupply of it from the artery under ligature.

In the tendons no ſwelling or inflation is obſerved; as, on account of their great degree of cloſeneſs, no blood can force into their cavities.

§. 444. The muſcles are homodromous leavers, in which the point of the power is nigher the centre of motion, than the point of the weight. For, the power of the muſcle is in its belly, and the centre of motion

motion at its head; whereas the point of the weight is at its moveable end (§. 20.)

§. 445. And therefore the force of a muſcle is always greater than the force of the weight, conſidered in and of itſelf, without being ſuſtained and moved by the muſcle as a leaver. An example will explain this: ſuppoſe D C B, fig. 9. plate VI. to be an arm extended horizontally, and round the fingers of the flat hand B a ſtring to be flung, at which in G a weight R hangs. The force, whereby this is ſuſtained, is in the muſcles D C, which extend with their tendons from the ſhoulder D to the place of the elbow at C. At *o* is the centre of motion, and conſequently the perpendicular line *o* I, which may be drawn from *o* on the line of direction of the tendon C I, the diſtance of the power; and the perpendicular line *o* B, which may be drawn from *o* on the line of direction of the weight B G, the diſtance of the weight (§. 19.) The force of the muſcle, exerted at I, is therefore to the force of the weight, inverſely as the diſtance of the weight *o* B to the diſtance of the power *o* I. *Borelli* in his book *De motu Animalium*, P. 1. propoſ. 22. writes, that *o* B is above 20 times greater than *o* I. So that the force of the muſcle D C is above 20 times greater than the weight R, when conſidered apart. A ſtout young man may with his fingers hold a weight of about 26 lb. with the arm extended in the manner above deſcribed. Now *Borelli* hints on this occaſion, that to this weight we are ſtill to reckon the

the half weight of the elbow and hand. The whole weight is to be fought for at H in the centre of gravity of the elbow and hand, as a leaver; and consequently the one half of this weight to be reckoned to a half of this leaver, and the other half of the weight to the other half of the leaver. But both elbow and hand of a ftout young man weigh 4 lb. And thus to the weight R at the hand there ftill accrue 2 lb. And therefore the force of the mufcle is 20 times greater than the force of 28 lb. And thus if 28 be multiplied by 20, the product is 560. In this manner the force, with which the mufcle draws the elbow, and feeks to bend it upwards, is ftronger than the force of 560 lb. on confidering them apart.

§. 446. But though the motion of a mufcle can no otherwife happen than by a great expence of the force; yet this expence is compenfated by the quicknefs with which the weight moves. For, the velocity of the weight in B, for inftance, is to that of the force of the mufcle at I, as the diftance of the weight *o* B to the diftance of the force *o* I (§. 31.) So that, in this example, the motion of the weight is 20 times quicker than the motion of the power.

§. 447. As the force, with which a fwelled mufcle acts, arifes from the nervous juice infinuating into the tranfverfe or annular fibres; it remains to enquire, how the force of the mufcle can be thereby fo great; as this juice is fo fubtle, as not to be diftin-

diſtinguiſhable by the naked eye. A matter may be ſubtle and inviſible, and yet be very ſtrong in its effects, as appears from the power of the air and of the magnetick matter. As the cavity of a muſcle is divided into ſeveral ſpaces by the annular fibrils, the degree of power, with which a muſcle ſwells, ariſes from the number of the ſingle forces, with which the ſingle annular fibrils are contracted by the influent nervous juice. And though its force in a ſingle fibril is ſmall, yet the force of the whole muſcle may be very great, when the number of the ſaid fibrils is alſo very great. As force and action are mutually proportional, or the intenſeneſs of the force may be judged of from the greatneſs of the action or effect; ſo the degree of power of the nervous juice, which inſinuates into the tranſverſe fibrils of a ſingle ſpace, might be eſtimated, could we find the proportion of the diameter of the diſtended ſpace, to its half height. By propoſition 117 of *Borelli*'s book *De motu Animalium*, P. 1. this matter may be exhibited as follows: let two ſtrings be faſtened together at A and B fig. 10. plate VI. and the upper part with a nail X at an immoveable body, hanging on at the under part a weight Z. Let the one ſtring A C B be pulled in the middle at C towards F; and the other in the middle at D towards G. The forces pulling towards F and G are to the force of the weight Z, as the line of diſtance C D is to A E, half the length of A B from the point A to B. For, if you remove aſunder

both ſtrings from the middle line, in which they touch each other; each ſtring has the form of two inclined planes. And thus if the ſtring A C B be pulled from the line A E B towards the point F, there ariſe the inclined planes A C E and B C E. The length of the firſt is A E, and of the ſecond B E, and the height of both is C E. But A E = B E, as the point C is in the middle of the ſtring. Did the force at C and the weight Z barely act on the inclined plane B C E againſt each other; the force would be to the weight, as the height C E to to the length B E (§. 24.) Suppoſe C E to B E as 1 to 2. And thus two pounds in Z might be ſuſtained by one in C. But as the force C acts by means of two inclined planes, whoſe lengths are mutually equal; it ſhould ſeem, as if the power in C were to the weight in Z, as the height C E to the double length, that is, to A B, and conſequently as 1 to 4. So that it appears, as if the two pound weight could be ſuſtained by a power of half a pound. For, $\frac{1}{2}$ lb. is to two whole pounds, as 1 to 4. But the power at C muſt act not only againſt the reſiſtance which Z cauſes, but alſo againſt the reſiſtance at the nail X. This reſiſtance is as great as the reſiſtance at Z. And thus if the power at C acts by means of theſe two inclined planes, you muſt take the height C E twice, and one time compare it with A E, and another with the equal length B E. So that it is all one, as if the power acted by means of an inclined plane, whoſe length were A E B and height C E taken

taken double. And C E taken double is to A E B, as 2 to 4, when C E is to B E as 1 to 2. But 2 is to 4, as 1 is to 2. And therefore it is a neceſſary conſequence, that the power in C is to the weight in Z, as the height C E to the length B E; as being half the diſtance from the point A to the point B. In like manner it may be ſhewn, that the power at D is to the reſiſtance of the weight Z, as D E to B E. And thus when both forces act together againſt Z, the power of both taken together againſt the reſiſtance of the weight is, as the line of width C D, which contains in it the heights of both inclined planes, to the length B E, or to the length A E, equal thereto, as being the half of A B. Suppoſe C D to be the thouſandth part of A E, Z might contain 1000 lb. and yet be ſuſtained by 1 lb. ſo a half pouud acted from C to F, and a half pound from D to G, or ſtretched and pulled.

Suppoſe two ſtrings to be bound not only above at A and below at C, fig. 11. plate VI. but alſo in the middle at B, in ſuch a manner as within the binding to admit of being drawn to and fro. Drive nails at D, E, F and G into the board, at which the ſtrings hang down, and ſo ſtretch the ſtrings aſunder, as to lie withoutſide the nails at D, E, F and G. If you croſs the ſtrings, in removing them aſunder, you need no binding at B. Both the intermediate diſtances D E and F G may be equal, and equally diſtant from the point B. Roſe therefore the weight an inch high by one ſingle ſuch widening of the

ſtrings, it would riſe two inches high by the ſaid two widenings. And thus the greater number of ſuch widenings were made, the higher would the weight be raiſed. For inſtance, according to fig. 12. there are eight equal widenings, and the weight comes eight times as high as when there is a ſingle widening only. But by the number of equal widenings you ſave no power. For inſtance, in fig. 12. the two ſtrings are croſſed into eight checkered ſpaces. And conſidering them ſingle, and apart, in each the power is to the weight, as the line of width to the half length of the ſpace, as was at firſt ſhewn. And therefore taking all the eight ſpaces together, the powers taken together in them are to the weight, as eight ſuch lines of width to eight ſuch half lengths. Suppoſe a line of width to be one, and a half length two inches; the forces together would be to the weight, as eight to 16. Did therefore the weight R weigh 16 lb. you muſt have 8 lb. for the power. If you take the undermoſt ſpace alone, 16 lb. indeed may be ſuſtained on letting eight half pounds act on each ſide thereof, and thus eight whole pounds together. For, the power in each ſpace is to the weight, as the line of width to the half length thereof. But thence we are not to conclude, that by connecting the eight ſpaces, the powers would be put in ſuch a condition, as to render the eighth part only of the powers, which act ſingly in the undermoſt ſpace, neceſſary. For, by the eightfold widening, the length from below

upwards

upwards is eight times ſhorter. And thus if we conſider the connection of all the eight ſpaces, as a ſingle inclined plane, and take in each ſpace the line of width one, and the half length two inches, the the height of this compound inclined plane is to the length as 8 to 16. And if thus the 16 lb. weight riſes eight times higher by the eightfold widening, you have juſt eight lb. to apply for the forces, whereby it is to be ſuſtained, as you required in the undermoſt ſpace alone; when the height which 16 lb. were to be ſuſtained at, was the eighth part only of the height, to which it was raiſed by the eightfold widening. Yet though by the number of equal widenings no power is ſaved, there notwithſtanding accrues a double advantage therefrom. For, firſt, the length of the ſtring is ſhortened ſo many times, and conſequently the weight raiſed ſo many times higher, as are the number of widenings. Secondly, as the forces may be always applied at the greater number of places, the more widenings there are; ſo in the caſe, where a certain force cannot be applied to a ſingle place, much ſmaller forces, as parts thereof, may be made to act at different places. For, the force of an eight pound body cannot by the alone help of the undermoſt ſpace in the figure, ſuſtain a 16 lb. weight eight inches high, for inſtance. But yet it may be done by eight ſingle pounds, when applied to eight ſuch ſpaces, mutually connected.

Laſtly, What cannot be effected by help of the checkered ſpaces of two ſtrings, may by two, three, and more pairs of ſtrings, and mutually ſo croſſed, that the ſpaces thereby ariſing ſhall exhibit the meſhes of a net, fig. 13. plate VI. Suppoſe there were three pair, each equal to the other in number, magnitude and ſtoutneſs of ſpaces. Now if a pound power be in a condition to ſuſtain two pound weight at a certain height by the ſpaces of the one pair; by a three pound power would be ſuſtained a ſix pound weight at the ſaid height.

When the ſpaces of a fleſhy fibre are according to *Bernouilli*'s explication ſo expanded, that in each the diameter of the breadth $p\ q$, fig. 8 and 7. plate VI. is greater than the diameter P Q in the unexpanded ſpace: this expanſion, indeed, happens by no ſuch forces, as, according to *Borelli*'s direction, are to be applied externally to the ſtrings, in order to draw them aſunder. But what is performed by the external forces in the caſe of the ſtrings, is in the caſe of the fleſhy fibres performed by the nervous juice, when the annular fibrils are contracted by its influx. The more therefore there are of ſuch annular fibrils, whereby a fleſhy fibre is divided into certain ſpaces, the nervous juice may act on the more places. And if thus a ſmall portion of the nervous juice forces directly into a ſingle annular fibril, many ſuch portions act together on many fibrils. And if ſuch a portion of the nervous juice has a ſmall quantity of matter, ſo on the contrary its motion

tion is the quicker, as the muſcle begins directly to act, ſo ſoon as the ſoul deſires it ſhould. But the quicker the motion of a body, the intenſer its action (§. 37.) As, laſtly, a muſcle conſiſts of ſeveral fleſhy fibres, ſo there is a greater quantity of the quick influent parts of the nervous juice.

MEMBER II.

Of the ORGANS of SENSE.

CHAP. I.

Of the ſeveral SPECIES of the ORGANS of SENSE.

§. 448. THESE organs conſiſt in a combination of nerves and other parts and matters of an animal body; in which the nerves are adapted to be ſo touched or excited, that the ſoul, inhabiting the animal body, directly perceives the motion ariſing in the nerves. The ſkin of an animal body is full of nerves, ſo united together, as by the magnifying glaſs to appear as ſo many *papillæ*, on ſeparating the cuticle, with which they are covered. So ſoon as this cuticle is puſhed or preſſed, or hurt by a body, the ſubjacent nervous *papillæ* are irritated,

irritated, and the ſoul has a ſenſation thereof, which is called the *touch*. The tongue is covered with three tunicles, of which the undermoſt is the fineſt, called *tunica papillaris nervoſa*, as in it the nerves in like manner run together into *papillæ*. And theſe, if touched by the moveable parts of the meat and drink, cauſe in the ſoul the ſenſation, called the *taſte*; yet there are other parts beſides, in the mouth, as the gums, that belong to the organ of taſte. The cavities and inner part of the noſe are encompaſſed with a mucous tunicle, full of nerves. When theſe are touched by the ſulphureous, ſaline and other ſharp effluvia, which move up and down in the air, there ariſes in the ſoul the ſenſation of *ſmelling*.

§. 449. The ear, by whoſe means the ſoul perceives ſound, conſiſts of the following parts, whoſe nature and combination form the organ of hearing. In the external part are ſeveral grooves and cavities, which catch the ſound. The deepeſt is called the *concha*, from which the ſound is conveyed into a winding tube, partly cartilaginous, partly bony, called the *meatus auditorius*. This *meatus* is the beginning or fore part of the internal ear, or of its inner part. Behind at the end of the *meatus auditorius* lies what is called the *tympanum* or drum, which has a thin membrane, ſtrung with a nerve drawn underneath over an oval, excavated, bony barrel. And there we find three little bones connected together, the *malleus* or hammer, the *incus* or anvil, the *ſtapes* or ſtirrup. The hammer lies on the anvil, and the

the anvil refts on the ftirrup. If now the membrane of the drum is irritated by a vibration of the external air, thefe auditory bones are bent. The ftirrup has its place in an aperture, called the *feneftra ovalis*. And then follows the *labyrinth*, or the innermoft winding cavity, in a very firm bone, and confifts of three parts, the *veftibulum* or entrance, the three femicircular channels, and the *cochlea*. The *veftibulum* is the middle cavity of the labyrinth; into it goes the faid *feneftra ovalis*. Alfo the three femicircular conduits have by five different holes a communication with the *veftibulum* or the middle cavity of the labyrinth. Next the *cochlea*, which has two or more fpiral windings, goes an aperture, which is ftretched over with a membrane, and called the *feneftra rotunda*. All the fides and furfaces of the labyrinth are lined with an extreme fine nervous membrane, which vibrates, when the external undulating air ftrikes on the membrane of the drum, and thereby puts into motion the auditory bones.

§. 450. The eye, in which the motions of light render bodies vifible to the foul, is a ball, which chiefly confifts of five tunicles, and contains three forts of humours Externally are two tunicles, which give firmnefs to the eye, for the other tunicles with the humours to remain fteady in their place. The one of thefe two tunicles forms the fore part of the eye or ball, and is called the *cornea*; and is tranfparent, and covered with a white membrane, called the *adnata*, which renders the eye-ball fmooth.

The

The other forms the hinder part, and is called the *ſclerotica*, and is opake. Under theſe two membranes, connected with each other, are two others, which in like manner join together; of which the foremoſt lies under the *cornea*, and is called the *uvea*; and the hindermoſt has its place under the *ſclerotica*, and is called the *choroides*. In the *uvea* is a round hole, called the *ſight* or *pupil*, and wider in a weak light, and narrower in a ſtrong. Round the ſight goes a coloured circle, which appears through the *cornea*, and is called the *iris*. At the hinder part of the inner cavity of the eye, under the *choroides*, is, laſtly, the *retina*, which is weaved of nervous fibrils, ariſing from the optick nerves. The three humours of the eye have the following names; one, the *aqueous*; the ſecond, the *vitreous*; and the third, the *cryſtalline*. The aqueous fills the fore part of the eye under the *cornea*, and is like a clear water, and by its humidity keeps the *cornea* tranſparent, and the *uvea* moveable. The vitreous humour is quite clear and tranſparent, and ſoft like a jelly, and behind fills up the greateſt ſpace in the cavity of the eye, and holds the *retina* expanded on it. Between the vitreous and aqueous humours lies the cryſtalline; which in like manner is tranſparent, and reſembles a burning-glaſs convex on both ſides. It is encompaſſed with a very fine membrane, called the *arachnoides*, ſerving to prevent both the other humours from mixing therewith. And the vitreous humour alſo, to prevent its being diſturbed,

is

is in like manner incloſed in a fine membrane, called the *hyaloides*.

CHAP. II.

How we ſee by the EYE.

§. 451. THE rays of light, which come from a body to the *retina*, form an image thereon, which exhibits to another eye the body reverſed. For inſtance, on the hinder part of an eye near the optick nerve cutting off a piece of the *ſclerotica*, and leaving the *retina* expanded behind; if you hold this eye againſt a burning candle, ſo that its rays fall through the *cornea*, and look behind at the *retina* laid bare on the eye; you ſee the point of the image of the flame of the candle formed thereon, turned downwards. One of the principal cauſes of the inverted image is the refraction of the incident rays in the three humours, particularly in the cryſtalline. For this laſt being on both ſides convex, in the manner of a convex lens, it muſt ſo refract the rays, which fall upon it from a body, as that the upper ones ſhall go behind it downwards; and the under, upwards; and thoſe coming from the left hand, go to the right; and thoſe from the right, to the left, on the *retina* (§. 202). But alſo in the abſence of the cryſtalline humour, external bodies muſt appear inverted on the *retina*, when they are bigger than the ſight or pupil (§. 149.)

§. 452.

§. 452. Notwithſtanding this, the ſoul through her own eye ſees the external body delineated in it, in that poſition in which it is without the eye. The reaſon whereof is to be ſought for in the reaction of the nerves on the rays of light, falling on them. But the nerves react in the lines, in which the rays of light act on the nerves. For inſtance, ſuppoſe in F, fig. 13. plate III. to be the focus of the cryſtalline humour, and behind it in C O to be the *retina*. Before the eye let the line O M B C have its poſition. Now act the ray, which comes from the point C into the eye, in the line C N C, on the point C of the *retina*; this point C reacts, along CNC againſt the luminous point C to the right. And thus the ſoul ſees to the right the extremity C, which actually ſtands to the right. Act the ray, falling from the other extremity of the line O M P C along the line O K O on the point O of the *retina*; this point O acts along the line O K O. And thus the ſoul ſees to the left the extremity O, which has actually its place to the left. In this manner the points of the line O M B C muſt appear in the ſituation, which they actually have.

§. 453. One ſees a thing diſtinctly, when he can diſtinguiſh the different parts thereof from each other. And in order that this may happen, in the firſt place, in the image of a body on the *retina*, each part of it muſt be exhibited diſtinct with a certain degree of intenſeneſs; and ſecondly, none of the images of the ſingle parts muſt be blended with the

images

images of other things. This laſt is avoided, if not only acceſs is denied to adventitious light, that may convey images of other things into the eye; but alſo if the light incident on the internal ſurface of the eye can be little or nothing reflected, and come on the *retina*. This reflection is prevented by the black colour of the *choroides*, and the ingreſs of adventitious light by the nature of the pupil, as being partly a narrow aperture, and partly contracting itſelf on a great flow of light to it. Alſo both the external tunicles are ſo denſe or cloſe, that no light can inſinuate through them into the cavity, in which the vitreous and cryſtalline humours lie. To the particular repreſentation of the ſingle parts of a body on the *retina*, and to that degree of intenſeneſs, whereby the nerves of the *retina* are ſufficiently irritated, partly the purity and tranſparency of the *cornea* and of the three humours, partly the due diſtance of the *retina* from the cryſtalline lens, are neceſſary. If in the aqueous humour there is a matter, which ſettles like a pellicle or film before the cryſtalline humour, and obſtructs the pupil, it is called a *cataract*. But if the cryſtalline lens is become opake, this diſorder is called a *glaucoma*. If the *glaucoma*, or cryſtalline lens become opake, is depreſſed by the couching-needle, the patient, after compleating the cure, requires convex ſpectacles, in order to ſee diſtinctly. For, by the refraction, which the rays undergo in the cryſtalline humour, they become diverging behind it, which is neceſſary in order to diſtinguiſh

ſtinguiſh the parts of a body, from which the rays come into the eye. And thus come the cryſtalline lens or humour to be wanting, the rays will be more diverging, and hereby form an undiſtinct image. But if convex ſpectacles come before the eyes, the rays are ſo refracted through them, that they run to the *retina* ſo wide aſunder, as if they paſſed through the cryſtalline humour. So that a man, in whoſe eye a filmy cataract has been depreſſed or couched, can ſee diſtinctly without ſpectacles. When the optick nerve and the *retina* loſe their ſenſe, the blindneſs thence ariſing is called *gutta ſerena.* As to the difference between the *glaucoma* and cataract, *Mery* and *de la Hire* in the memoires of the academy of ſciences for the years 1707 and 1708 give good hints to that purpoſe.

CHAP. III.

Of the SHORT-SIGHTED and the AGED.

§. 454. TWO perſons A and B may view a body C at one and the ſame diſtance = D. And the perſon A may ſee it diſtinctly, and B undiſtinctly. Both of them may approach the body C in equal proportion. If the perſon A ſee the body undiſtinctly on approaching to it, he is called a *preſbyta*, who better diſtinguiſhes one and the ſame thing at a diſtance than near at hand. On the other hand, if the perſon B, on approaching, ſee

fee the body C diftinctly; he is called a *myops*, or purblind, who better diftinguifhes one and the fame thing near at hand than at a diftance. The nature of the *prefbytæ* and *myopes*, and the caufes of their feveral defects, *Sturmius* has fully explained in his *Philofophia eclectica*, T. 2. Exercitatio 10.

§. 455. The rays, flowing from a luminous point, run indeed diverging; but if the diameter of the furface, on which they fall, is as little, as the diameter of the ray in the eye, they appear to be lefs diverging, and confequently more parallel, when the object is diftant from the furface: and on the contrary, their divergency to increafe, when the object comes nearer to the furface (§. 144.)

§. 456. The rays, by which a *myops* fees more diftinctly, are thus in regard to the eye of a *prefbyta* to be deemed diverging: and the rays, whereby a *prefbyta* fees diftinctly, are in refpect to the eye of a *myops* to be held as parallel. We may therefore in general affirm, that the *myopes* fee diftinctly by diverging, and the *prefbytæ* by parallel rays.

§. 457. And hence concave glaffes are of fervice to the *myopes*; but convex to the *prefbytæ*, in order to fee more diftinctly what otherwife appears undiftinct. For, *thofe* make the incident rays to diverge by the refraction (§. 183.) *thefe* on the contrary, to converge (§. 176.) and thus leffen the divergency, with which the rays fall from a luminous point on the furface of the glafs.

§. 458. A *myops* therefore cannot diſtinctly ſee an object, which a *preſbyta* ſees diſtinctly; as the focus, which the rays, refracted through the cryſtalline humour, form, is ſo diſtant from the *retina*, that its nerves are not irritated ſtrong enough by the rays, which fall from the luminous points of the object into the eye. For, the rays, which exhibit an object diſtinctly to a *preſbyta*, fall into the eyes of a *myops* parallel with their axis. But the focal diſtance of a glaſs lens is ſhorter, when the rays fall parallel on it, than when they come on it in diverging lines (§. 180.) And therefore the rays, which are propagated in the eye of a *myops* from the focus of the cryſtalline lens in diverging lines, have a longer way to the *retina*, than in the eye of a *preſbyta*: and therefore irritate not ſo ſtrongly the nerves of the *retina*, as in the eyes of the laſt.

§. 459. A *preſbyta* therefore cannot ſee an object diſtinctly, which a *myops* diſtinctly does; as in his eye the focus of the cryſtalline lens is ſo far diſtant from it, that the rays, which fall from the luminous points of the object into the eye, are not ſufficiently parted aſunder on the *retina*. For, the *preſbyta* ſees undiſtinctly by diverging rays (§. 456.) If diverging rays are refracted by a glaſs lens, the focus falls more diſtant, than when the rays fall on the glaſs lens parallel with its axis (§. 180.) And thus the focus of the cryſtalline lens in the eye of a *preſbyta*, when diverging rays fall into his eye, is nearer to the *retina* than in the eye of a *myops*; ſo that the rays

cannot

cannot run ſo far aſunder from the focus in the eye of a *preſbyta*, before they come on the *retina*, as in the eye of a *myops*.

§. 460. And thus if an object is diſtinctly depicted in an eye, be it either ſo near, as to appear undiſtinct to a *preſbyta*; or ſo diſtant, as to be undiſtinguiſhable by a *myops*; this eye muſt be ſo qualified, as that the focal diſtance may now be lengthened, again ſhortened. Both may happen, ſo either the rounding of the cryſtalline lens is variable, as by help of the muſcles to be now enlarged, again diminiſhed; or the cryſtalline lens and *retina* be now brought nigher to, again farther from each other. If the rounding is leſſened, the focus falls more diſtant from; but if enlarged, nigher to the lens. For, a glaſs ſphere projects the focus only half ſo diſtant, as a glaſs, convex on both ſides, which is a portion of an equal ſphere (§. 178. ſeq.)

§. 461 In the eye of a *myops* the focus is therefore too diſtant from the *retina*, either as the cryſtalline lens is too round, and its rounding admits of no diminution by help of the muſcles; or as the *retina* and the cryſtalline lens cannot be brought nearer together. The laſt incapacity ariſes through cuſtom or habit, when a man for a long time views objects at a leſs diſtance than he need. The firſt inability may ariſe as well from a bad habitude, as alſo from nature.

§. 462. In the eye of a *preſbyta* the focus is therefore too near the *retina*, either as the cryſtal-

line lens has too little rounding, and admits not of being enlarged; or as the *retina* aud the cryſtalline lens cannot be removed from each other. The eye comes to the laſt defect through cuſtom, when for a long time viewing objects at a greater diſtance than is neceſſary at firſt for diſtinctneſs. And this very cuſtom may alſo bring on the firſt defect. Yet too an eye may originally have a too flat cryſtalline lens.

CHAP IV.

Of ſingle and double VISION.

§. 463. AS an object is depicted in both eyes at once, it proves a matter of wonder, why it is not ſeen double? The reaſon thereof will be clear from the following circumſtances. Among the different rays, which flow from a ſingle point of an object into the eye, that paſſing through the centre of the eye, is called the *optick axis*. If, for inſtance, one eye is in A, fig. 1. plate VII. the other in B, and the luminous point without them in G; A G and B G are both the optick axes. By G A the *retina* in the eye A is irritated, and by G B the *retina* in the eye B. So that the nerves in A react in the optick axis A G; and in B, in the optick axis B G. Now if both theſe optick axes run together in a certain point without the eye; both reactions of the optick nerves will unite in one point, and hereby form one ſingle reaction. So that the

ſoul

ſoul can diſtinguiſh and ſee an object only as ſingle. The line H I, drawn through the concourſe of the optick axes A H and B H in H, and of the axes AI and B I in I; and running parallel with the line A B, which paſſes through the centre of the eye, is called the *horopter*.

§. 464. If therefore the eyes are in ſuch a ſtate, as that both the optick axes do not mutually interſect, the object appears double; for inſtance, in D and E. This happens, when, for example, one holds a ſlender oblong object, as a knife, or ruler, about a foot diſtant from the noſe, and with both eyes ſtedfaſtly views C over the end lengthwiſe. Alſo when a man is either very drunk, or ſhort-ſighted, and accuſtomed to view diſtant objects, as the moon, with one and the ſame eye through a concave glaſs. And in the *Swediſh Acta literaria* for the year 1721, mention is made of a boy, who had had a hurt in the left eye by a ſnow-ball; with which, indeed, in ſome months after he began again to ſee, but each object, on which he fixed both eyes, double; and thus he continued to ſee.

CHAP. V.

Of the Magnitude of the Image in the EYE, and of the Object without it.

§. 465. THE magnitude of the diameter of an image, formed in the eye on the *retina*, may be determined as follows: if from the extremeties B and E, fig. 2. plate VII. of an object B E, the rays B A and E A fall at A through the eye on the *retina*, the diameter of the image formed is D F. As the triangles D A F and B A E are mutually ſimilar; ſo is A E : E B : : A D : D F. If A E = 30 E B = 1, and A D, as being the diameter of the eye, in like manner = 1 inch; D F the diameter of the image is = $\frac{1}{30}$ of an inch. For,

$$A E : E B :: A D : D F$$
$$30 : 1 :: 1 : \tfrac{1}{30}$$

If B E is a tower 4000 inches high, and A E its diſtance 120000 inches; the diameter of its image on the retina is in like manner only $\frac{1}{30}$ of an inch: for, 120000 : 4000 : : 30 : 1.

§. 466. The more diſtant therefore an object is from the eye, the ſmaller is the diameter of its image on the *retina*. The diſtance of a thing to its height ſuppoſe to be as 300 to 1; the diameter of its image is $\frac{1}{300}$ of an inch: for, 300 : 1 : : 1 : $\frac{1}{300}$.

§. 467. How tender or ſubtle therefore muſt be the fibrils, of which the *retina* conſiſts? But the

rays

rays of light themſelves are infinitely ſubtle (§. 148). *Muſchenbroeck* in his *Inſtitutiones phyſicæ*, §. 1241. relates, that a ſilk thread $\frac{1}{1948}$ of an inch thick is ſtill diſtinguiſhable by the eye, when lying on a paper at the diſtance of 40 inches. The diameter of its image in the eye is $\frac{1}{77920}$ of an inch. For,

$$AE : EB :: AD : DF$$
$$40 : \frac{1}{1948} :: 1$$
$$\text{i. e. } \frac{40}{1} : \frac{1}{1948} :: \frac{1}{1} : \frac{1}{77920}.$$

This laſt number ariſes, ſo you multiply the product $\frac{1}{1948}$ of the ſecond and third fraction according to the rule of fractions, by $\frac{1}{40}$, the firſt fraction reverſed, inſtead of dividing it.

§. 468. But if the image on the *retina* be leſs than the object itſelf, the query is; how it is poſſible, that yet the ſoul ſhould repreſent to itſelf the object bigger? The bigneſs or ſize of the repreſentation, which the ſoul has of the object, ariſes from the number of the perceived actions, with which the incident rays of light touch and irritate the different fibrils of the *retina*. The ſoul repreſents to herſelf not the image, which is formed on this coat, but by help of this image, the object only; as ſhe perceives and diſtinguiſhes the actions of the rays of light, coming from the object and ſtriking on the *retina*. The ſpace, which the image occupies, is leſs than the ſpace without the eye, in which the ſoul repreſents to itſelf the object. But in the ſmall ſpace of the image ſhe obſerves ſo many actions as there are in

the ſpace, in which the object appears, and from which the rays of light propagate their actions quite to the *retina.* The thing may be illuſtrated by a microſcopical inſtance. A ſquare inch is conſtantly leſs than a ſquare foot. But yet a ſquare inch may with a magnifying glaſs appear as big, as a ſquare foot without. The reaſon whereof is, becauſe the magnifying glaſs conveys ſo many rays from the ſquare inch into the eye, as come into it from the ſquare foot, when viewed without a microſcope. And thus the ſoul perceives ſo many actions of different rays of light, when viewing the ſquare inch through the magnifying glaſs, as when without it, the ſquare foot.

CHAP. VI.

Of the SPACE, which may be ſurveyed or viewed at once.

§. 469. THE ſpace, which one ſees under a certain angle (§. 193.) is always within the limits of a right angle. Suppoſe from the point A of the ſurface A D, fig. 3. plate VII. the perpendicular ray of light A O to fall into the eye O. From the point D, which ſuppoſe ſo diſtant from A as is poſſible, let the other D O come into the eye. As the angle at A is a right angle; ſo the angle A O D is leſs than a right. And thus the ſpace, which the eye can take in, is within the limits of a right

right angle. Take a ſquare board A B C D, fig. 5. plate I. and draw from A to C the diagonal, by which the right angle at A is biſſected. On the line A C fix two pins, and lay one eye at the angle at A, and look along the ſtaves or pins, of which the one next the eye covers the other. There will nothing be ſeen of what is without both the legs A B and A D.

§. 470. If therefore the ſemidiameter of an object C H, fig. 9. plate III. is equal to its diſtance H A from the eye, you ſee with one eye at once the object fully, but alſo nothing further beyond its limits, when the ray H A forms on both ſides right angles on C D, and under right angles goes through the middle of the diameter of the ſight in the eye. For, as C H = H A; ſo the angle A C H is = the angle C A H. Now as the angle C H A is a right angle; ſo is the angle C A H half of a right angle. In like manner it is clear, that the angle DAH is half of a right angle. The angle C A D is thus a right angle. And therefore the entire object C H D may be diſtinguiſhed at once quite to its limits C and D.

§. 471. But if the diſtance H A was leſs than the ſemidiameter C H, the object C H D could not be fully ſurveyed at once. For, in this manner, as well the angle C A H, as alſo the angle D A H would be greater than half a right one, and conſequently C A D greater than a right one.

§ 472. And thus the nigher one is to an object, the lefs thereof he fees with one eye at once; but the more diftant one is from it, the more with one caft of an eye may be feen beyond its limits. As the lines A C and A D, which at A include a right angle, may be infinitely produced; fo the eye at an infinite diftance can with one look take in an infinite fpace, when from an infinite diftance rays of light come into it. And hence one ftanding furveys at once the wide heavens between the horizon and vertex as well ftraight forwards, as alfo to right and left. But if one lays himfelf on his back, the eye takes in the whole half heavens or hemifphere. For, the line, which at right angles biffects the diameter of the fight in the eye, and may be produced ftraight on to the limits of the heavens, forms right angles with the horizontal lines, which may be drawn from the centre of the fight, or pupil, quite round to the limits of the horizon.

§. 473. No fphere can be feen at once for the half of it. The eye in R, fig. 4. plate VI. in order to reach at once to the points O and L, at which the diameter of the fphere O S L terminates; the angle O S R would be meafured by a quadrant, and confequently be a right angle, and thus the line R S ftand perpendicular on O S. In like manner the ray R O would be a line, ftanding perpendicular on O S; as each right line, which is a tangent to a circle and forms an angle with its radius, is a perpendicular. Two lines, ftanding perpendicular on a third,

third, are mutually parallel. And thus ſo far as the ray R O is at O diſtant from S, ſo far too muſt it be diſtant from the eye in R. But in that manner it can form no angle with R S in the eye, which is neceſſary for viſion. And thus too the eye cannot fully take in at once the hemiſphere.

CHAP. VII.

Of the Appearances of OBJECTS at different Diſtances.

§. 474. MAgnitude, figure, place and motion of an object appear to be different at different diſtances. Be a body never ſo big, yet it ſeems as a point only, when its diameter is ſeen under an angle of a ſecond. Let the diameter of the object be E G F, fig. 4. plate VII. and the ſemidiameter E G, and the diſtance from the eye G A = ſix inches. If the angle of viſion E A F = 1 ſecond, the half thereof E A G = ½ ſecond. The line A G forms with G E a right angle at G. If therefore in the point A you place the leg of a compaſſes, and the other leg in G, and begin deſcribing a circle from the point G; A G is its ſemidiameter, and conſequently to be conſidered as the ſine total, and E G as the tangent of the arch G H, and conſequently as the tangent of the angle of viſion, or of the apparent magnitude (§. 193.) E A G, as what is meaſured by the arch G H. So that by trigonometry

metry you conclude as follows. As the whole ſine A G to the tangent E G of the half apparent magnitude E A G; ſo is the diſtance A G to the true half magnitude E G. The ſine total is = 10000000, and the tangent of a half ſecond = 24. The calculation therefore is as follows:

Sin. tot. A G : Tang. E A G : : A G : E G

$$10000000 \; : \; 24 \; :: \; 6 \; : \; \frac{144}{10000000}$$

The whole diameter E F is thus $= \frac{288}{10000000}$

Dividing numerator and denominator by 288, E F is $\frac{1}{34722}$ of an inch. And ſuch a part is juſtly deemed a point.

§. 475. Two objects A B and A C, fig. 5. plate VII. may be equally big, and be equally diſtant from the eye in a point A: and yet A B appear bigger than A C: this happens when the ray A D, which is the diſtance of the common point, forms at A with A B a right angle, and with A C an oblique. For, if A D form with A C an oblique angle, the angle C D A, under which C A is ſeen, is leſs than the angle B D A, under which A B appears (§. 193.)

§. 476. If the eye O, fig. 6. plate VII. ſtands between two parallel lines A B and C D, and looks ſtraight on, that the line, which may be drawn in the middle between A B and C D, ſhall paſs through the centre of the pupil and its diameter; the parallel

rallel lines appear to come ever nearer together, the more diſtant they are from the eye. For, the more diſtant intermediate ſpace B D is ſeen under a leſs angle than the nearer F E (§. 193.)

§. 477. If therefore theſe parallel lines are ſo long, that the angle of viſion, under which their intermediate ſpace appears, is a ſecond only; they ſeem to concur in a point, and there to ſet limits to the ſight of the eye (§. 474.) And hence the point of a tower appears to bend forwards when one is near it. For, if the eye in D looks towards B, fig. 7. plate VII. the angle at A is a right one. If from the eye D you draw the line D E, to run parallel with the height A B; the angle A D E is alſo a right one. Theſe parallel lines A B and D E appear gradually to run together, on looking between them to the point of the tower. And thus the diſtant points C and B of the line E D appear to be nearer than the points below in the tower.

§. 478. If therefore one of the parallel lines is higher, and the other lower than the eye; *this* appears at laſt to raiſe itſelf, and *that* to lower itſelf, ſo as to appear to have both one and the ſame height with the eye. From theſe reaſons, the parts more diſtant on the ſurface of the earth, on which we have a diſtant proſpect, appear to be higher than the nearer: and in the air the more diſtant clouds to ſtand lower than the nearer. As the parallel lines, which may be imagined to be drawn from the feet on the earth towards any point, and in

in the air over the head, proceed ſo far, that their limits cannot be determined; ſo the angle, under which the infinite diſtance between the ſaid parallel lines would be ſeen, is undiſtinguiſhably ſmall. And thus the appearance muſt prove, as if the heavens lay on the earth (§. 477.) Such parallel lines may be drawn out infinitely quite round the ſpectator. So that the heavens all around ſeem to be on the earth in all points of an unaſſignable diſtance from him, and thus form the horizon (§. 385). The heavenly ſpace has the figure of a concave hemiphere; as the angle of viſion, which the rays form, falling from the horizon and the vertex into an eye directed upwards, has a quadrant for its meaſure; and all lines, along which one looks between the vertex and horizon, run out infinitely, and therefore no one can be deemed ſhorter than the other.

§. 479. Though the flame of a burning body ſhould at a diſtance, on account of the ſmaller angle of viſion, appear ſmaller, than near at hand: yet at a diſtance it appears larger, ſo the viewing eye is in a dark place. For, firſt, the air round the flame is illuminated thereby: ſecondly, the flame by means of the air between it and the eye, acts ever weaker on the eye, the more diſtant the eye ſtands: thirdly, the eye can perceive the illuminated air, as being itſelf in the dark, and thus no other light acting on it. If therefore the light of the flame is ſo weakened by the great diſtance, as to act no intenſer on the eye than the illumination produced in the air; the

the eye cannot diſtinguiſh it from the flame. So that the eye ſees a light ariſing both from the flame and its illumination of the air. The diameter of this illumination may be five inches, and the flame one inch. So that the flame, and the diſtance, at which the eye cannot diſtinguiſh it from its illumination of the air, muſt appear bigger than nearer at hand, where it may be diſtinguiſhed.

480. When on a long line A D E, fig. 3. plate VII. on which we may have a proſpect, we aſſume a point D at a certain diſtance, and from it have the remaining length divided into equal lines D *f*, *fg*, *g* E; they ever appear under a leſs angle, the more diſtant they are from the aſſumed point. At length the angles of viſion become undiſtinguiſhable. And then the lines appear as points. And as the angles are no longer diſtinguiſhable from each other; neither can we any longer diſtinguiſh the lines to be ſeen under them. Suppoſe A O is to A D, as 1 to 57. Place in O, where the eye is, the leg of a pair of compaſſes, and the other in A, and therewith deſcribe an arch; and A O is the whole ſine, and A D the tangent of the angle of viſion A O D. The tangent you find on concluding as follows: as A O to A D; ſo is the whole ſine to the tangent of the angle of viſion.

Logarithm	A O	0. 0000000
Logar.	A D	1. 7558748
Log. ſin. tot.		10. 0000000
Log. tang.		11. 7558748

And

And looking in the table of ſines and tangents for the number, that comes neareſt to this, you find at it 89° for the angle of viſion.

If therefore an eye is ſix feet high above the line A D, it commands a length of 342 feet, when the angle of viſion is 89°. For, A O 1 : A D 57 : : 6 feet : 342 feet. Suppoſe A O : A D : : 1 : 3437, the angle of viſion A O D is = 89° 59′. If you take at firſt the length A D = 57, which one commands under an angle of 89°, the remaining length is 3380: which thus appears under an angle of 59′. And thus if the eye is ſix feet high above the line, the length, which it commands under an angle of 89° 59′, is 20622 feet. For 1 : 3437 : : 6 : 20622. And thus an eye, which is elevated ſix feet above a line, can, after a diſtance of 342 feet on that line, ſee a length of 20000 and more feet, under an angle only of 59′.

§. 481. An arch A C B, fig. 8. plate VII. appears therefore as a right line C D E, when the lines F D and B E, by which the lines O F and O B are longer than the line O C, drawn from the eye through the middle of the arch at C, are ſeen under undiſtinguiſhable angles. For, the arch C B and the right line C E appear under one and the ſame angle, and conſequently are equal (§. 193.) If therefore neither F D be diſtinguiſhable from D O, nor B E from E O; ſo neither can the half arch C F B be diſtinguiſhed from the right line C D E. In like manner it may be ſhewn, that the eye in the other

other half arch A C can neither in the magnitude nor in the diſtance find any thing, by which to be able to diſtinguiſh it from the right line beginning at C.

§. 482. A ſphere or a ſpherical body appears thus to be a circle, or a diſk; when ſo far diſtant, as that the arches of their convex ſurfaces, which ſtand oppoſed to the eye, appear to it as right lines.

§. 483. An angular body A B C D appears to be round, when the angles A, B, C, and D are, at the diſtance, at which the eye views the body, perceived under undiſtinguiſhable angles by it. For in that manner, the eye can perceive no angles.

§. 484. If the diſtance between two bodies can be ſeen under no diſtinguiſhable angle (§. 474); the bodies appear to touch each other; as for inſtance, the vapours, which at a diſtance appear a miſt, and on high, clouds.

But if rays of light fall between two clouds, which appear to touch each other; theſe are a ſign that the clouds are parted aſunder. If one of theſe clouds covers the ſun from the eye, and its rays enlighten the vapours aſcending between both clouds; they will become viſible to the eye under the form of white ſtreaks; at the ſight of which we uſually ſay, *the ſun draws water.*

§. 485. If an object in C, fig. 9. plate VII. has from D and E the diſtances E D and C E, which the eye, be it either in A or in B, can diſtinguiſh under no conſiderable angle; the object appears to be in

in D, when the eye is in B; and in E, when the eye is in A. And thus if the object C be viewed at the ſame time by two obſervers from A and B, it appears to one to be in a different place from what it appears to the other. The place C, which the object actually occupies, is called its *natural place*: on the contrary, the more diſtant places D and E, at which it appears to be, are called the *optical places*. The diſtance between two optical places D and E is called the *parallax*, or *difference of place*.

§. 486. If therefore an object at reſt in C is thus diſtant from A and B, it appears to run from E to D, when the eye proceeds ſtraight on from A to B.

§. 487. If object and eye move towards one and the ſame part; as the object from B to F, fig. 10. plate VII. and the eye from A to E; and the motion of the eye is ſwifter than the motion of the object; the object appears to run backwards from C to G.

§. 488. If two objects B and E, fig. 11. plate VII. of which B is nearer the eye than E, move equally ſwift; the more diſtant E appears to have a ſlower motion than the nigher B. For, as they have both equal velocities, they at the ſame time paſs over the equal ſpaces B D and E F. But the more diſtant ſpace E F appears leſs than the equal nigher ſpace B D (§. 193.) So that it appears, as if E, in the time, in which B is come to D, had paſſed over a ſhorter ſpace, and conſequently moved ſlower.

If

If therefore the eye, during this motion, continues in the place A, the nearer object appears to go on before, and the more diſtant to come after. Suppoſe alſo, that E moved ſomewhat ſwifter than B; but that the difference of velocity was not very conſiderable, yet B might appear to be ſwifter.

§. 489. If the velocity of the nigher object B fig. 11. plate VII. is to that of the more diſtant E; as the diſtance A B = 1 to the diſtance A E = 2; both objects appear to be equally ſwift. For, while both objects move in equal time; their velocities are as the ſpaces run through, B C and E F (§. 27.) And thus too B C : E F : : 1 : 2. And conſequently B C : E F : : A B : A E. Moreover, the ſpace B C is parallel to the ſpace E F. And thus there ariſe two triangles A B C and A E F, which have the angle at A common. And thus the eye in A ſees the ſpaces finiſhed in equal times under one and the ſame angle. And as thus theſe ſpaces muſt appear equally great to it; it can alſo obſerve no difference between the velocities.

§. 490. If an object E moves never ſo ſwift, yet it appears to be at reſt, when the ſpace E G, which it finiſhes in a ſecond, has an undiſtinguiſhable ratio to the diſtance E A from the eye fig. 11. plate VII. For, G E is the tangent of the angle E A G, and A E the ſine total. And therefore too the tangent G E has an unobſervable ratio to the ſine total. So that alſo the angle, under which E G is ſeen, muſt

be undiſtinguiſhable to the eye, and conſequently the object appear to have continued in its place.

In the ſpace of a ſecond we can perceive no motion in the moon with the naked eye, though ſhe muſt have finiſhed in that time an arch of 15 ſeconds, ſuppoſing ſhe moved round the earth in 24 hours. The ſpace E G, a tangent of the angle E A G of 15 ſeconds, is to the diſtance E A, the ſine total, as 727 to 10000000; that is, almoſt as 1 to 13755. And if thus the ſpace compleated in a ſecond is to the diſtance of the object from the eye, as 1 to 13755; the eye in a ſecond can obſerve no motion in the object, be it otherwiſe never ſo ſwift.

§. 491. If two very diſtant objects A and B move equally quick towards the ſame part; for inſtance, from A to C; but C remains at reſt; it appears, as if A and B were at reſt, and C moved from the place C towards A, fig. 12. plate VII. As A and B have equal velocities, none of them comes nigher to the other, and conſequently each in reſpect of the other appears to be at reſt. But if both paſs by at C, and conſequently C hereby acquires another poſition; it appears, as if C moved contrary to B and A. If the moon appears through clouds, that move quick, ſhe ſeems to move, for inſtance, from eaſt to weſt, ſo the clouds are driven quick from weſt to eaſt.

§. 492. The reaſon, why a body appears to have a motion, not proper to it, is the motion of its image on the *retina*. If therefore the eye with its body moves

moves ſo quick, that the times, in which, among the images of unmoved objects, one ever moves into the place of the other, are undiſtinguiſhable; the objects, which ſtand oppoſite to the eye, appear to run or croud together thereon; and thoſe that are ſideways immoveable, to paſs cloſe by it with great velocity. If the ſoul knows, that her body moves, and that the objects, which appear to move, have a fixed poſition; this apparent motion only cauſes wonder. But if neither be otherwiſe known to her, ſhe aſcribes to the immoveable object an actual motion, when ſhe has no knowledge of the cauſes of the apparent motions. In order therefore to avoid, in the caſe of an apparent motion, when one knows not, whether the object or the eye with its body moves, the danger of a falſe judgment, we muſt neither aſcribe nor deny to the object an actual motion.

CHAP. VIII.

Of the MOTION of the NERVES in SENSATION.

§. 493. THO' a nerve ſhould appear only like a ſlender thread, yet it is put together of many fibrils, each of which conſiſts of a white matter, and is cloathed with a double tunicle, between which a certain liquor is found. In a nerve no thicker than a briſtle, *Leeuwenhoeck* diſcovered by the magnifying

glaſs to the number of 30 ſmall nerves, and each of them with its own tunicle. In a ſmall nerve, of the thickneſs of a hair, the magnifying glaſs ſhewed to the number of 20 ſlender nerves of different thickneſs. He cut off ſmall ſlices of a nerve, as thin as a hair of a beard, and in each ſlice he found a cavity. In many he could diſtinguiſh theſe cavities ſo plainly, as the ſmall holes made with a fine needle in paper, and through which the ſun may be viewed. But as the fluid matter, which is in theſe holes, directly evaporates, theſe cavities as ſoon collapſe or fall together, and come to be undiſtinguiſhable. But in order to exhibit to the eye of the artiſt, whom he employed to draw, theſe ſmall ſlices and nervous veſſels, he cauſed to moiſten them. Yet as notwithſtanding this, the ſides of the cavities mutually touched in ſome meaſure, there appeared, as if a line run through each ſmall veſſel. And hence alſo in the ſecond figure of his copper plate for letter 32, he cauſed ſo to draw the ſmall nervous veſſels, as to appear round, and as the ſign of their cavity, to have in the middle a black line. The ſlender ſmall nerves, from whoſe combination a greater nerve ariſes, are exhibited, fig. 1. In letter 36 he relates, how he took ſome nerves out of the ſhoulder of a lamb, and in one of them, whoſe diameter was thrice as great as that of a hair of a beard, diſcovered 1000 ſmall veſſels. From ſuch ſmall veſſels a nervous fibril takes its riſe, in rows one above another. In fig. 2. of the copper plate for letter 36 by means of the magnifying

ing glaſs he cauſed to draw a nervous fibre, in which the ſmall veſſels proceed lengthwiſe, having cut it in that direction.

§. 494. Preſſion and impulſe, which happen at the outmoſt extremity of a nerve, are propagated thro' it with incredible velocity. For, ſo ſoon as they ariſe, ſo ſoon are they made known to the ſoul.

§. 495. So that we are to inquire, how ſo quick a propagation is poſſible through the nerves? If we hold them for ſtrung and elaſtick threads, and alſo aſcribe to their coats a degree of elaſticity, the velocity, with which a motion is propagated through a nerve, is an effect of the ſaid ſpring (§. 87.) But would we conſider the nervous juice as an elaſtick matter, and then the fineneſs of its parts; we might explain the velocity, with which a motion, made at the outmoſt extremity, is propagated through the whole nerve, by ſuch ſtrokes or pulſes, as Mr. profeſſor *Euler* diſtinctly explains the propagated motion of light by (§. 211.) A ſimilar example of ſuch a propagated velocity the electrical matter affords. Let a chain be never ſo long, it has been found, directly to manifeſt at the end thereof the effect of the electrical force, ſo ſoon as it aroſe at the beginning or other end. But as the coats of a nerve are firſt touched by an object, and conſequently impulſe and preſſion muſt be communicated to the nervous juice, in order to its propagation through it: ſo in the caſe of their having no elaſticity, they would put the nervous juice into a very ſmall degree of motion. We have therefore always reaſon

to aſcribe to the nervous coats a certain degree of elaſticity and tenſion.

§. 496. The tighter therefore the nerves are ſtrung, the more remarkably are they put into motion by a ſmall touch, and thus the more ſenſible is ſuch a touch. The tenſion may have ſeveral cauſes; for inſtance, when a member is extended, or when the coats of the nerves have a peculiar degree of elaſticity. Of this laſt quality may be the optick nerves in the eyes of thoſe animals, that commonly ſee in the dark. The nervous coats may be preſſed and ſtretched by the ſwelling of contiguous parts, and thereby be fitted for an extraordinary ſenſation.

This appears from ſeveral inſtances of wounded eyes which have the ſenſe of ſeeing in the dark; of which M. *Thumigius* adduces one in the 4th part of an experiment for explaining uncommon phænomena, and *Boyle* one in his *Exercitatio de natura determinata effluviorum*, c. 4. In like manner may the nerves acquire an uncommonly ſtrong degree of tenſion in peculiar diſeaſes. So Mr. *Boyle* knew a phyſician, who in a ſurpriſing ſort of a fever had gained an exceeding acute ſenſe of hearing.

§. 497. The violence of a ſenſation ariſes partly from the intenſeneſs of the preſſion or impulſe on a nerve, partly from the number of the motions, with which ſeveral fibrils are touched at the ſame time. For, it is a thing ſufficiently known from experience, that the ſenſation of a ſound may be intolerable to the ſoul, when the number of the ſingle tones is too great, though each

of

of them affords a weak ſenſation, when touching the ear without the others.

§. 498. A nerve of ſenſation vibrates, when an external matter ſo acts upon it, that its parts mutually impel and ſhake (§ 308). Into ſuch vibrations the auditory nerves happen to come by an intenſe ſound; and the nerves of touch by the force of an electrical ſpark, excited in *Muſchenbroek*'s manner. If a vibrated nerve ſtands cloſely connected with many other nerves of ſenſation and motion, its vibration will be alſo inſtantly communicated thereto. And thus if the vibration is intenſe, there ariſes among the many vibratory motions, excited in many and various nerves at once, a ſudden confuſion; in which the ſoul can diſtinguiſh nothing, and conſequently in the time this confuſion laſts, loſes its conſciouſneſs. Into ſuch a circumſtance one may be put for a ſhort time by means of electricity, when excited in *Muſchenbroek*'s manner, and acting on him through a yielding matter as a cap, which only touches the hair on the crown of the head. Such an accident I can remember ſince the year 1748; when unawares I happened to tread with my foot on a chain, which lay on a veſſel with water bottles, whoſe electrified water had communication with another chain hanging at ſilken ſtrings; and under this chain I ſtood ſo cloſe, that its electrical force reached the ſilver threads of my cap, and drew them up. At once my body was pervaded by a ſudden degree of heat, and in an inſtant I loſt the ability to recollect what

was befallen me; and I ſeemed to hear the ringing of the bells of St. *Thomas*'s church, that was not a great way off; that even as ſoon as I began to recover myſelf again, I ſaid to thoſe about me, the bells ſeem to be ringing.

§. 499. The impreſſions made on the nerves of ſenſation are of different duration. They laſt longeſt in the nerves of the touch, as appears from the continued pain or ſmart, cauſed by a ſtroke. Whereas in the auditory and optick nerves the duration of an impreſſion made ſeems almoſt undiſtinguiſhable. But that an impreſſion, which a ray of light cauſes in the eye on the *retina*, laſts a ſmall time, may be perceived hence, that the quick vibrations of a ſtring, and of a finger moved to and fro, appear to leave behind a viſible ſurface, and a glowing coal moved circularly round with great velocity, a fiery ring. The time, in which the coal accompliſhes the circle is a ſecond nearly. And thus ſo long are we to hold the duration of the impreſſion made on the *retina* by the firſt among the rays of light, that come into the eye from this deſcribed circle.

CHAP.

CHAP. IX.

Of the Propagation, Duration, and common Place of the ſenſible IMPRESSIONS.

§. 500. BE a nerve of ſenſation either preſſed or impelled by a material object, there will be changes produced in ſo many parts of the nerve, as theſe are parts with which the material object either preſſes or impels the nerve. Now be ſuch a change produced, how it will; the preſſed or impelled particles of the nerves muſt be moved ſomewhat out of their place. The order among the parts of a nerve moved in this manner is juſt ſuch as that in which either the preſſing or impelling parts of the material object happen to be. So long therefore as either the preſſion or impulſe laſts; a ſenſible impreſſion conſiſts in an order of moved nervous particles, which coincides with the order of the preſſing or impelling particles of the external object.

§, 501. As the nerves have a certain degree of elaſticity (§. 495.) ſo it is thence a natural conſequence, that the impreſſions, on the outmoſt extremities of a nerve, proceed inſtantaneouſly through it quite to the place of its origin; as one part ever communicates to the other, with which it is in contact, the conceived impulſe or preſſion.

§. 502. The place, where the nerves of the five organs of ſenſe ſtand connected together, is called the *common ſenſory*. But in what part in the head

it may be, the moſt accurate anatomiſts have not hitherto been able to affirm with any degree of certainty. The ſeveral opinions about it profeſſor *Langguth* has diſtinctly and ſolidly deſcribed in his diſputation, entitled *Communis Senſorii hiſtoria. Ridley* in his *Anatomia cerebri*, c. 17. gives a probable preference to the opinion of thoſe, who ſeek for the common place of the nerves of ſenſation in the outmoſt limits of the medullary ſubſtance of the brain, where it is encompaſſed with the cineritious ſubſtance. But at the ſame time owns, that with all his care he could never diſcover in any brain ſuch a connection of parts as the authors of this opinion form to themſelves. But now ſo latent ſoever as is the place, at which the ſenſible impreſſions at length arrive, yet from their duration, conſtancy and variety, ſome properties of this receptacle may be diſcovered.

§. 503. To the ſoul, often againſt her expectation and deſire, corporeal objects, which ſhe had formerly perceived, make their appearance; but which now, as they offer to her again, act not at all on the nerves of ſenſation. Now if the ſoul has formerly, on perceiving theſe objects by the ſenſible impreſſions, been excited to repreſent to herſelf the objects perceived; we can thence make no other concluſion, but that the ſenſible impreſſions muſt ſomewhere or other remain without the ſoul in her body, on the abſent objects unexpectedly breaking in upon her again.

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To deny this, you muſt ſhew, that they aroſe anew, either in the nerves of ſenſation, or in their common place, by means of certain internal motions. But whence ſhould theſe motions be excited? ſhould they take their riſe from the ſoul? The objects appear to her unexpected and undeſired. Should they be anew produced by the objects themſelves formerly perceived? Theſe are abſent, and can now by no means act on the ſenſible organs. Should the matter in the nerves and brain, by the former actions of the external objects, be put in a condition of coming at certain times into ſuch a mutual connection, as is equal or ſimilar to a ſenſible impreſſion? Let a figure be impreſſed in wax as often as you will, by and upon each other; and then let the impreſſed figures be ſmoothed over and blended together, ſo as all of them ſhall diſappear; and then let the particles of the wax be put in motion by heat; will ever any of the impreſſed figures make their appearance again, ſo either the particles of the wax are moved to and fro by the heat, or, on its decreaſe again, acquire a firm coheſion; if the figure be not anew impreſſed thereon?

§. 504. Many ſenſible impreſſions, which have ariſen in a man's firſt early years, remain all his life long in their common place or ſenſory. Many among them are ſo conſtant, as not to decay, tho' unrenewed again for 20, 30 or more years. For, at times there ariſe in the ſoul, againſt her will, ideas of objects, about which ſhe had no farther thought for

for 20, 30 or more years. Not many years ago, things presented themselves to me in dreams, that happened in my childhood, but which in all this length of time had never once offered themselves to me awake. Now if we consider, that such sensible impressions have not been quite disturbed, though for all this long tract of time the brain received every moment many other impressions; we may hence with good grounds conjecture, that the *common receptacle* or *repository of the sensible impressions*, or their *place of collection*, consists of uncommonly durable particles.

It is true, indeed, that thoughts of former old things are often wont to come into one's mind, either on perceiving something resembling a thing we long ago perceived, or otherwise thinking on other absent things, and having in the brain a variety of motions. And hence we might conjecture, that possibly the motions in the brain, and the new and similar sensible impressions in the parts thereof, caused such a connection, as coincided with a former old sensible impression. But, in case nothing of this former old impression is any longer extant, there is in the newly arisen connection of parts no trace of that, from which the soul can distinguish, that the objects, thereby represented, were formerly perceived, and are now absent.

§. 505. This common receptacle or repository, may therefore be entirely distinct from the soft substance of the brain. For, how otherwise should the sensible

ſenſible impreſſions retain therein ſo long and ſo undiſturbed a duration? As the juices, ſmall veſſels and tubes are ever undergoing one degree of decay after another, and ever one new recruit of the waſting matters after another.

To imagine, the ſenſible impreſſions were to be found in the waſting parts of the brain; and the new, replacing their waſte, as coming into their ſtead, alſo had their ſenſible impreſſions: it would remain to aſſign the reaſon, why ſuch motions ſhould be produced in the acceding and replacing particles, whereby the ſenſible impreſſions were ariſen in the waſting parts.

§. 506. It often happens, that thoughts drop into the ſoul without her ſeeking and labour, which ſhe had formerly either awake or dreaming combined together from ideas of ſenſible objects. Alſo at times one dreams of things, which he had formerly imaged to him in a dream. I myſelf had a dream, in which I ſaw a certain city, and in my dream believed, I had formerly been in that city, but could not recollect, when this could have happened. But as I awaked, I bethought me, that about five years before I had this very city preſented to me in a dream. And this is a ſign, that in the receptacle of the ſenſible impreſſions, there ariſe certain new combinations among them, when the ſoul connects together her ideas of ſenſible objects. Otherwiſe no reaſon could be aſſigned, whereby the ſoul ſhould have an occa-

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ſion given her for a thought, on which ſhe employs no labour.

§. 507. It does not, indeed, admit explanation, how the ſoul can combine together the ſenſible impreſſions. But ſhould any deny her the power of doing ſo; no reaſon could be aſſigned, by which the ſingle ſenſible impreſſions could be brought to a certain connection, on the ſoul's comparing together the ideas of ſenſible objects, and from many ſingle ideas putting together, for inſtance, an idea of a building, never yet erected, or of a machine, never yet executed.

§. 508. The common receptacle of the ſenſible impreſſions ſerves therefore partly for the ſoul to be able again to renew in herſelf the ideas and thoughts ſhe formerly had had of ſenſible objects; partly, by attending to the ſenſible impreſſions, find an opportunity to put together thoughts of corporeal objects, and thereby find out infinite combinations of ſuch thoughts. In regard to the firſt uſe, the common receptacle of the ſenſible impreſſions may be compared to an index, pointing to the contents of a book; and in regard to the laſt uſe, it may be conceived of, as a working-place or laboratory, in which the ſoul is buſied about her reflections on the objects and images to be found therein.

§. 509. The receptacle of the ſenſible impreſſions is not only ſubject to the actions of the nerves of ſenſation, from which it receives the impreſſions from

from external objects, but alſo to the motions of the brain. This laſt is perceivable from the nerves of ſenſation, ſtanding in the cloſeſt connection with the brain. And thus if a motion ariſes in the juices of the brain, the nerves of ſenſation in the brain cannot remain unaffected thereby.

§. 510. If therefore the juices of the brain come into any diſorder, there alſo ariſe diſorderly motions in the receptacle of the ſenſible impreſſions.

§. 511. So ſoon as in the ſaid receptacle a motion ariſes, ſo ſoon does an idea thereof ariſe in the ſoul, without the ſoul being able not to ſuffer this idea to ariſe in her. For, if a nerve of ſenſation is touched or affected, the ſenſation thereof in the ſoul is unavoidable. But the change produced in the nerve is inſtantly propagated to the place of its origin (§. 494.)

§. 512. So that the ſoul is neceſſitated to exhibit to herſelf alſo the diſorderly motions, which ariſe in her laboratory, from the diſorderly motions of the juices of the brain.

§. 513. If the ſoul, by ſuch motions, is hindered from conſidering the impreſſions made in her laboratory; or if they are put into diſorder, ſhe can uſe neither her memory nor her underſtanding in the caſe of objects, with whoſe ideas certain impreſſions are at the ſame time ariſen in the ſaid laboratory. For, ſhe thinks on and recollects a thing, formerly known to her, ſo the idea formed thereon preſents itſelf again before her, and ſhe beſides aſſured, that

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ſhe had had it before. But in order to aſſure herſelf thereof, ſhe muſt obſerve in the idea, anew ariſen, that very thing ſhe had obſerved therein on its firſt riſe. And this cannot more properly happen than if ſhe conſiders the impreſſion now actually exiſting in her laboratory, and adapted to this idea. And thus if hindered in this conſideration, neither is ſhe in caſe to recollect, that ſhe had formerly had an idea of this thing. For the ſoul, to think with underſtanding on a thing, and form a right judgment, when either affirming or denying any thing about it, ſhe has to compare the idea of the thing, about which ſhe would form a judgment, with the idea of what ſhe is to affirm or deny about the thing, and to attend to the agreement or diſagreement of theſe ideas. And if ſhe makes this compariſon, the ideas will be excited either with or without the ſenſation. With the ſenſation the ſoul can no otherwiſe receive an idea, than as a certain impreſſion is made in her laboratory (§. 501.)

If therefore the nerves of ſenſation are, by the nature and commotion of the blood and other juices in the body and brain, put into ſuch a condition, as that the motion excited by an external object in an organ of ſenſe, cannot be propagated to the receptacle of the ſenſible impreſſions; ſo neither can the ſoul receive any idea of the action of the object, and conſequently form a judgment about it. And thus it is poſſible for perſons, diſordered in their brain, ſo to mutilate their limbs, without perceiving any ſmart

or

or pain, which they might otherwise have from such an act. An extraordinary example of such a frantick person was in 1743 communicated to me from *Lauban* by a person of credit. In the *January* of that year a journeyman weaver there, who for a year and a half before had been afflicted with a melancholy disorder, gave himself with a sheers upwards of thirty stabs in the body, some of them only going any thing deep, and then he castrated himself. In binding up his wounds, he complained of little pain. In a few days after, as his friends had neglected to look after him, he snatched up a blunt hatchet, and cut off the foot above the ankle, in doing which he was obliged to fetch above eight strokes; and throwing away the foot, he hopped about the room on one leg. If a soul in her laboratory can unhindered consider the impressions extant; it is easy for her, in judging of a thing, to form to herself anew the ideas necessary thereto, which she had formerly imprinted in her. It is sufficiently known, how the thoughts flow in, as it were, upon the soul, when the juices of the body and brain have been heightened and exalted by certain meats and drinks; and how at other times, when one knows, a certain sluggishness prevails in the juices of the body, the finding out thoughts, or the invention, proceeds but slowly and with difficulty. If therefore the laboratory of the soul is by a distemperature of its body filled with confused motions, that either the impressions, made therein, fall into some disor-

der, or the soul cannot therefore consider them, as being swallowed up in too many irregular thoughts: the soul is thus incapable of judging rationally.

§. 514. In some men, that by severe sickness and other accidents have lost the use of memory and reason, such circumstances offer, that it should appear, as if this loss arose from the sensible impressions being entirely vitiated in their receptacles. Some persons disordered in their minds continue for a long time in their confusion, and never again recover the use of their understanding. In the great plague at *Athens*, described by *Thucydides* in his history of the *Peloponnesian* war, book 2. many persons had lost their memory; so that, after their recovery, they neither knew their friends nor themselves. But so easy as it might be to explain from the extinction of the sensible impressions, how it were possible, for a soul to come to be without memory and without understanding; so difficult is it to shew this extinction from the instance of these wretched persons. *Thucydides* has omitted to remark, whether the *Athenians*, deprived of memory by the plague, ever after came to be themselves, so far as to recollect that they lived before the time of the plague, and that these and the other persons were their friends and acquaintance. Many people, who continue disordered in their senses till their deaths, have at times what is called a lucid interval; when, for instance, they can regularly relate a fact, form a right judgment of certain things, and behave reasonably towards

wards the company present. A wine merchant of *Tarentum*, of whom *Aristotle* makes mention in his περὶ θαυμασίων ἀκουσμάτων, in the night time turned foolish and senseless; and on the contrary in the day time carried on his wine-business with good discretion, also carried the key for his things with so great care with him, that he never lost it, though attempts were made to trick him out of it. There are men, who immediately after a fit of madness talk and behave with understanding, and exactly recollect what they were conscious of before their wretched state. M. *Platner* in his programma, intitled *Medicos de insanis & furiosis audiendos esse*, makes mention of a woman, who for 20 years had been deprived of the use of her understanding, but recovered it again by a fall from a high rock, with the fracture of an arm. Were the sensible impressions, which were in the laboratory of the soul before the confuse state of this person, supposed to be entirely vitiated by the violent motions of the blood and other juices; how could this person, after the fall from the rock, be able to recollect again directly the things, which she had perceived and was conscious of upwards of 20 years before?

§. 515. If the confuse motions, arisen in the receptacle of the sensible impressions, are laid; the confusion of thoughts thence arisen in the soul, of course also ceases. For the first to happen, the juices of the brain, whereby the laboratoryof the soul has been disordered, must either no longer act thereon, or come

into their former order. But whether directly therewith the diforder, produced in the receptacle of the fenfible impreffions, ceafes, cannot fo abfolutely be either affirmed or denied. In the faid receptacle no motion can well arife, which fhould not for fome time, how fmall foever, leave behind it a trace. If thefe traces have a certain degree of ftrength, they may, notwithftanding the order reftored in the brain, caufe the foul to think diforderly: and this diforder give occafion to a new difturbance in the juices of the brain; as the foul, fo long as it ftands in intercourfe with her body, never once thinks, but at the fame time a certain alteration precedes in the body. And this may be reckoned among the reafons, why many perfons who have been freed from phrenzy and madnefs, after fome time relapfe again.

§. 516. For, this not to happen; the traces of confufion, left behind in the laboratory of the foul, muft either difappear, or become undifcernable to the foul. Difappear, when other impreffions come in their place. Become undiftinguifhable to the foul, when not renewed by any new motion, and the foul is with-held from perceiving them by the excitation of other thoughts. For a foul therefore to be confirmed in her reftored ufe of reafon; it is requifite partly, to ufe proper means, whereby the juices of the body may continue in their order again reftored; partly, to avoid the occafions whereby the traces of the confufion may be renewed; partly, to employ the nerves of fenfation on fuch motions, whereby in the

laboratory of the ſoul orderly and lively impreſſions may ariſe, which excite the ſoul's attention, and gradually wean her from thinking on any thing of the old diſorder of her ideas.

§. 517. The ſoul is wont to form judgments as well awake as aſleep. But awake fitter for it than aſleep. If we beſides conſider, that awake ſhe often forms affirmative and negative judgments, for which ſhe uſes not the ſenſible ideas, ſhe at the ſame time acquires by the nerves of ſenſation; it comes to be matter of wonder, what ſhould hinder her, to be as fitted to form judgments aſleep. If ſometimes the organs of ſenſation are ſtrongly acted upon by external objects, it proves hard for the ſoul to conſider the ideas of ſuch objects, as ſhe then perceives not. In ſleep ſhe is ſet free from ſuch impediments. And why thus may ſhe not juſt with as much eaſe and juſtneſs form judgments aſleep, as awake? The reaſon of this is in the body, and we may explain it as follows. The ſoul, in order to form judgments of objects, which ſhe perceives not, muſt produce again in herſelf the ideas, which ſhe had formerly of them; and as well in the caſe of each in particular attend to what it exhibits, as alſo compare one idea with another, and obſerve their agreement and diſagreement. For inſtance, in the idea of the ſun is contained at the ſame time the idea of roundneſs. And hence ariſes the judgment, viz. the ſun appears round. If ideas ariſe anew in the ſoul, with which at firſt there were at the ſame time in the la-

boratory of the ſoul certain impreſſions made; the ſaid impreſſions will be alſo excited again. And ſo long as ſuch an impreſſion is in motion, and remains diſtinguiſhable above others; ſo long alſo the idea, which ſtands in a certain relation therewith, laſts in the ſoul (§. 503. 506). If therefore the receptacle of the ſenſible impreſſions is in ſuch a ſtate, as that the ſoul can conſider one impreſſion after the other by a certain time, and in each perceive the particular parts; it is eaſy for her to form judgments of the objects; the ideas of which have a reference to the impreſſions: whereas it muſt be difficult for her, when the receptacle of the ſenſible impreſſions is put out of that ſtate. This happens, when the impreſſions made therein fall, by the actions of an external cauſe, into ſo many motions, that the ſoul cannot ſufficiently conſider any one impreſſion; or are intermixed with ſo many new and conſtantly interchanging impreſſions, that the ſoul is not able to direct her attention and reflection on the impreſſions, formerly made; from the conſideration of which ſhe is to form judgments on certain objects. Such actions may be cauſed as well by bodies, which exiſt without the organs of ſenſe, as alſo by the juices of the brain. Experience teaches both. How often are not men rendered inſenſible for ſome time by a fall, a violent pain, a flaſh of lightening? How many men fall not by the tainted juices of their body into a confuſion of thoughts? And ſuch people too awake are not maſters of their underſtanding.

But

But as awake we can intelligently form judgments, when body and brain are ſound; we may hence with good grounds conclude, that the ſoul awake is therefore more fitted for forming judgments than aſleep: as at the time of being awake, in conſidering the impreſſions made in her laboratory, no ſuch impediment is made to her by the actions of the brain, as at the time of being aſleep.

This would appear more diſtinctly, could we circumſtantially explain what may be the caſe with the nerves of ſenſation, when they are ſpent and weak, and cauſe ſleep.

Awake the ſoul diſtinguiſhes two ſorts of impreſſions in her laboratory; ſome exhibiting corporeal objects, which act on the nerves of ſenſation: but others, ſuch objects, as at this time cauſe no motion in them. The external action, whereby the firſt ariſe, is ſtronger than the action, whereby the others are again put in motion. And therefore the firſt are more diſtinguiſhable by the ſoul than the laſt. And ſo the ſoul obſerves this difference, ſhe knows, how far ſhe thinks on objects, which at the very time ſhe thinks on them, act on the organs of ſenſe; and how far her thoughts are directed on no ſuch objects. And as thus awake ſhe cannot confound together both theſe thoughts; ſhe is alſo the more fitted to form judgments of each in particular.

§. 518. As the ſoul awake can judge intelligently of objects, which act not on the organs of ſenſation, when the impreſſions formerly ariſen in the labora-

tory of the ſoul, which have a reference to theſe objects, remain in ſuch a condition, as that they may be conſidered as well apart, as alſo compared together; it may hence be concluded, that at the time, when the ſoul aſleep thinks regularly of ſuch objects, the impreſſions extant in her laboratory are in ſuch a condition, and therefore are not diſturbed by the juices of the brain in motion. The thoughts of the ſoul aſleep are called *dreams*. So that the reaſon is clear, why the ſoul ſometimes thinks, forms judgments and concluſions, as regularly aſleep as awake. *Gaſſendi* in his Phyſicks, ſect. 3. membr. poſter. lib. 8. c. 6. and baron *Wolfius* in his *Pſychologia rationalis*, §. 419. adduce ſome remarkable inſtances thereof from their own experience. From the examples, which I have from time to time marked down for my own uſe and recollection, I perceive, that many times dreaming I have told the years paſt, and bethought me of times, in which certain things had happened; recounted to one perſon the life of another; given advice in dubious and important caſes; made reflections on the divine providence; put judicial queries in caſes otherwiſe unknown to me, alſo heard ſuch queries put and anſwers made; noted down a variety of different things; tranſlated out of one language into another; heard a long *German* poem, which I had never before known, read to me by a known friend; I have either reflected on the nature of dreams, or on account of a thing, which offered in dreaming, ſtarted the doubt, whether it might

might not be a dream; or held dreams for dreams; or when I have been in cares, have dreamed, that I ſtruggled, not to awake; made addreſſes both in *Latin* and *German* to perſons living and dead; aſſiſted at a learned diſpute about the origin or etymology of a word; and on that account turned over a variety of dictionaries; made and delivered harangues; read over whole pages and leaves in writings, which I never once had a ſight of; made definitions and formed concluſions in the firſt figure; ſhewed certain perſons into what whims people have fallen in different branches of learning; I have made a variety of inquiries into things, that regard the ſoul; as for inſtance, how in ſenſible things one muſt diſtinguiſh what is actual from what is apparent; how a thinking ſubſtance differs from a body; whence the ſoul took its riſe; what we are to hold about *Pythagoras*'s opinions of the ſoul; into what condition the ſoul is to happen after the death of her body; whether to fall into a long dream, or directly attain to think of new objects.

§. 519. Sound ſleep is properly a ſtate, in which the ſoul can therefore by the organs of ſenſe attain no clear ſenſation, as they all of them are tired or ſpent. If not all tired, the ſoul ſleeps not ſound, but wakes ſtill in part, in regard to the clear ſenſations ſhe acquires by certain nerves of ſenſation. Some years ago I heard an officer of experience in a very reſpectable company relate, how ſometimes he had been obliged to march with his men, but ſo

ſpent

ſpent and fatigued, that he and his men marched on as it were dreaming, as in going their eyes conſtantly fell together; adding this remark, that he could ſcarce have believed, one could, as it were, go dreaming, had he not known it from his own experience. The moſt remarkable ſpecies of a ſleep, not ſound, is that of the night-walker, in which barely the nerves of feeling or touch, have the due activity to bring into the laboratory of the ſoul ſuch impreſſions, whereby the ſoul is capable of perceiving the corporeal things, by which the nerves of contact are affected. Now as moſt objects, which otherwiſe become known to the ſoul by the eye, may be perceived by the touch; hence it may be ſeen, that the actions of a night-walker are properly undertaken not aſleep but awake. The activity of the nerves of feeling conveys to a night-walker in the night, when as to the reſt of the nerves he is aſleep, even as ſtrong impreſſions into the laboratory of the ſoul, as in the day-time, when the nerves in the other organs of the ſenſes have their due degree of activity. So that the ſoul, by conſidering the impreſſions made by the nerves of touch, can diſtinguiſh the corporeal objects, which act on the nerves of touch, as clearly in the night, as ſhe diſtinguiſhes in the day the objects that may be felt. If one conſiders this, the wonder at what night-walkers uſually do, will be in ſome meaſure abated. There are men born blind, who by the long uſe of their touch are little ſhort of thoſe with eye-ſight, in the perception

ception of objects. A night-walker, at the time he is such, has just as intense a touch as a blind man, when awake. To the state of ordinary waking, when all the nerves of sensation have their due degree of activity, the vivacity of the nerves of touch contributes just as much, as a species of the other nerves. So that in a night-walker, by the activity of the nerves of touch, also the juices of the brain are so with-held, as to be able to produce nothing in the laboratory of the soul, whereby the soul might be hindered in the due consideration of the impressions extant therein.

§. 520. As the impressions in the laboratory of the soul consist in a certain order of the parts (§. 500, 501.) and consequently are something individual and compound or corporeal; the query is, whether the soul, when she thinks either on something incorporeal, or something general or universal, can find any thing in her laboratory, that should give occasion thereunto? For what similitude has the individual with the general, and the corporeal with the incorporeal? What should the soul, for instance, when she thinks on God, on a spirit, on herself, find in the repository of the sensible impressions, that could in any measure only agree with herself, with a spirit, with God? What can be done in this repository, that should represent in general a substance, for instance, a force, an effect? And thus it appears, the soul might consider universal and incorporeal objects, be her laboratory

disposed

disposed how it will. But yet experience teaches, that the consideration of these objects, ever the better succeeds with her, the less her laboratory is disturbed by the juices of the brain. We are therefore to enquire, what may be therein, on which the soul, also in thoughts on general and incorporeal objects, directs her attention.

A *general object* is nothing other, but what different objects have in common with each other. And thus the soul distinguishes something general, when in the ideas of different things she observes what indicates their coincidence or agreement. For instance, on comparing the ideas of the bodies of men and beasts together, she observes, that in both sorts of bodies life and spontaneous motions appear. And thus representing to herself something animated and with spontaneous motions, she thinks on a general object. The first ideas, in which she begins to separate or abstract the general, exhibit individual sensible objects, certain impressions of which are brought into the laboratory of the soul (§. 500, 501, 503, 504). And thus beginning to form to herself ideas of general objects, on considering individuals, she observes in some impressions, made by individual objects, what is contained in the one as well as the other. And therefore as to the thoughts or notions, in which the soul at first begins to represent to herself general objects, there is always something in her laboratory, to which she refers, or what is one and the same in some individual impressions. If

in

in the ideas of ſome general objects, which differ mutually from each other, ſhe ſeparates or abſtracts that, by which they are not different; or what theſe general objects have in common with each other; ſhe thinks on things ſtill more general. Now as certain impreſſions, extant in the laboratory of the ſoul, refer to the firſt general objects; there is alſo ſomething in them, that has a certain ratio with the ſtill more general ideas. For inſtance, if the ſoul of a child ſees at firſt a number of dogs, ſhe forms to herſelf ſome ideas of individual dogs; then again a number of cats, ſhe forms to herſelf ſome ideas of individual cats. But ſhe attains theſe ideas, if at the ſame time ſenſible impreſſions, which repreſent theſe individual or ſingular animals, ariſe in her laboratory. If in the ideas of theſe two ſorts of individual animals, ſhe obſerves as well what the ſingular dogs have in common with each other; as alſo that, which the ſingular cats agree in with each other; ſhe forms to herſelf two general ideas, the one of which repreſents a dog in general; and the other, a cat in general. But what ſhe thinks in general of of a dog and of a cat, juſt that very thing ſhe finds and diſtinguiſhes alſo in the ſenſible impreſſions, which reached the laboratory of the ſoul from the individual dogs and cats by the nerves of ſenſation. From theſe two general ideas ariſes one ſtill more general, when the ſoul attends to that, which dogs and cats, conſidered in general, are mutually alike in. In both, ſhe diſtinguiſhes four feet, organs of ſenſe

and

and ſpontaneous motions. And thus ſhe forms to herſelf the ſtill more general idea of a four-footed animal. But what ſhe alſo thinks in this more general idea of a four-footed animal, that very thing ſhe ſtill finds and diſtinguiſhes in the ſenſible impreſſions which have ariſen in her repoſitory, as ſhe perceived the individual animals. So long therefore as the ſoul, in the ideas of corporeal objects ſeparates the general, ſhe always thinks on ſomething, that is not indeed repreſented in her laboratory as general, but yet ſingular in individual impreſſions.

If the ſoul thinks on any thing incorporeal, there is nothing at all in her laboratory, which ſhould have even ſo much as the appearance of an image thereof. But, this notwithſtanding, in a thought on an incorporeal object certain ideas are contained, which either repreſent ſomething corporeal, or have ariſen by conſidering corporeal objects and ſenſible impreſſions. The ideas of the firſt ſpecies offer, when the ſoul diſtinguiſhes an incorporeal object from a corporeal. The ideas of the ſecond ſpecies mix themſelves in, ſo we have occaſion, in the caſe of a thought of an incorporeal object, for certain general ideas. The ſoul may take the thoughts, ſhe forms on herſelf and properties as inſtances. When ſhe reflects, that ſhe thinks, ſhe repreſents to herſelf, by her thinking, an action, in which ſhe diſtinguiſhes one idea or one object from the other. But in the idea, with which ſhe thinks on this action, is there not contained the general idea of an action,

action, and the general idea of diftinguifhing in general? How has fhe attained thefe general ideas? Has fhe not gradually feparated them from the ideas of different actions, which fhe came to know by the fenfes? If fhe confiders the fpecies of her forces or powers, fhe by that means gets the general ideas of forces and powers in general. But whence have they their origin? Have they not been feparated or abftracted from the ideas of the forces of different bodies? By confidering herfelf, fhe forms to herfelf the idea of a fpirit, as under it fhe reprefents to herfelf an incorporeal fubftance, with underftanding and free will. Such a being can be reprefented or imaged by nothing corporeal. But thinks the foul on it without the general idea of being or fubftance in general? And has fhe not formed it in herfelf, on obferving in the ideas of individual and fenfible fubftances what in all of them is one and the fame? Confider we the notion of God. By it we underftand the moft perfect fpirit, who formed, and governs the world. But can we think on this, without having at the fame time the general ideas of an active caufe and of a governing being? And therefore it fufficiently appears, that the thoughts of the foul about incorporeal things are, in her prefent ftate, never free from ideas, which reprefent fomething, which the foul at firft had diftinguifhed in the impreffions of her laboratory.

And thus the more undifturbed the foul can direct her attention on the impreffions, extant in her laboratory,

laboratory, the more opportunity ſhe has, in conſidering them, to attain the ideas, without which it is not poſſible for her in this life to think either of any thing general, or of any thing incorporeal.

§. 521. From the long and ſteady duration of the ſenſible and other impreſſions in the laboratory of the ſoul it appears, that it muſt be different from the ſoft ſubſtance of the brain, by an uncommon degree of firmneſs (§. 505, 506, 514). Alſo theſe parts muſt be of a quite different nature from the firm matters, which are diſtinguiſhable in the brain and head. For, how ſoon and eaſily do not the extant impreſſions come again into motion, when either a new impreſſion ariſes by the nerves of ſenſation, or the ſoul meditates on ſomething! Conſider we, beſides, the number of the impreſſions, which the laboratory of a ſoul contains, that is exerciſed in different languages and ſciences: we can make no other concluſion, but that this laboratory conſiſts of incredibly ſubtle parts. For, in the head and brain there is nothing diſtinguiſhable, that ſhould exhibit this laboratory. But yet innumerable impreſſions are contained in it. And thus it muſt be a corpuſcle, which conſiſts of innumerable parts; and yet ſo ſmall, as to remain indiſtinguiſhable by the ſenſes. But the ſmaller a whole, and the greater notwithſtanding the number of its particles, the more ſubtle they are.

§. 522. We have therefore no reaſon to apprehend, that the laboratory of the ſoul is like the brain

brain and the other viſible parts of the head and body ſubject to corruption. And thus a philoſopher can affirm nothing further about the death of the man, but that the ſoul quits the viſible body. *Cudworth* in his *Intellectual Syſtem*, c. 5. ſect. 3. §. 24. adduces ſeveral places from *Irenæus*, *Origen* and other fathers for this opinion. But he himſelf at length ſays: "What hinders a man, encompaſſed only with a covering or cloke, afterwards to take a plain gown and a looſer attire? And this will appear much leſs wonderful, if we reflect that even in this very life we have now a double body; one, more external; the other, more internal. Beſides that unwieldy body, that may be touched and ſeen, we have another ſpiritual and more internal body, which our ſoul uſes as an inſtrument to perceive and cauſe motions with. And this internal body is not committed to the earth along with the exterior, nor placed in keeping under the green ſod." Thus far *Cudworth*.

§. 523. In the mundane ſpace there is no want of matters, which in ſubtlety are equal to the moſt ſubtle parts, with which the nerves of ſenſation act in the laboratory of the ſoul. We need go no farther than light or pure æther (§. 148, 212). So that the firm, ſubtle and durable ſubſtance which forms the peculiar habitation of the ſoul in this preſent life may, after that her commerce with her viſible body ceaſes, be very fitly affected by certain matters, or gain from them ſuch impreſſions, where-

by the ſoul attains a knowledge of corporeal things, which by the ſenſible organs of her preſent viſible body ſhe cannot diſtinguiſh.

§. 524. When the ſoul has, by the imagination, an idea of an abſent; and by the ſenſation, of a preſent object; ſhe recollects the abſent as abſent, by this means, viz. that the idea thereof has a leſs degree of clearneſs than the idea of the preſent object, which ſhe perceives. And thus in like manner the ſoul in the life to come may recollect her ſeparated body and her former ſtate, ſo ſhe remain united with her laboratory. For, as its ſtructure is by far too firm, to be diſſevered by the motions, whereby barely the viſible body moulders or conſumes away; ſo it does not appear, that by the mouldering thereof, the ſenſible impreſſions, whereby the ſoul has learned to diſtinguiſh an infinite number of times her own body and other corporeal objects, ſhould become indiſtinguiſhable to her in her laboratory. If therefore in the life to come impreſſions of objects, otherwiſe unknown, reach her abode, ſeparated from the viſible body; by conſidering and comparing together the new and the old impreſſions ſhe is in a condition to diſtinguiſh her new manner of life from the old, and thereby to recollect objects and occurrences, with which ſhe was acquainted in the preſent life, and in her union with the preſent viſible body.

MEMBER III.

Of the Generation of animated BODIES.

CHAP. I.

Of the Species of ANIMALS, in regard to Generation.

§. 525. TO generate is to produce one's like. If two bodies are furnished with organs, whose concurrence is necessary to this purpose, to both of them we ascribe a sex.

§. 526. Some animals have no sex, and yet they produce their like, as the fresh water polypus and mildew.* The last is described by *Leuwenhoek* in his 90th and 134th letters; and the former by M. *Trembley* in his *Memoires pour servir a l' histoire d' un genre de polypes d' eau douce a bras en forme de cornes*, and also in N° 474 and 484 of the *Philosophical Transactions*, and by Mr. professor *Kastner* in the *Hamburgh* Magazine, T. 3. P. 3. in his account of three species of polypuses, which he had found near *Lipsick*. In N° 484 of the *Philosophical Transactions* M. *Trembley* describes the manner, in which different species of polypuses sitting in a group or cluster, multiply themselves. These small animals, says he,

* Called also by the *Germans* blade-louse.

have the form almoſt of a bell. Their fore extremity, in which is the mouth, and which may be conſidered as the head, is excavated inwards, and reſembles the open ſide of a bell. The other extremity ends in a point, and in this point a ſtalk is faſtened. When the polypus is about to divide itſelf, it firſt draws its lips inwards into the body; and then gradually aſſumes a round form. And immediately after that this ſmall ſpherical body is formed, it divides itſelf into two other ſuch ſpherical bodies. Theſe laſt open themſelves inſenſibly again in a few minutes. And then they loſe the ſpherical form, and turn to a bell, or appear juſt as perfect polypuſes, as that, by whoſe diviſion they were formed. Theſe are what M. *Reaumur* calls the noſegay-polypuſes, of which M. *Trembley* has made mention in N° 474 of the *Philoſophical Tranſactions*. They have this name, while, like a noſegay, they ſtrike out cloſe to each other. In N° 484 M. *Trembley* deſcribes the cluſter-polypuſes, which are ſmaller and whiter. The group and cluſter, which they form, ſits on one ſtalk. This ſtalk is with the undermoſt extremity faſtened to another body. From the other end go forth branches, which form obtuſe angles with the ſtalk itſelf. And from theſe branches at different places go forth other branches; and from theſe laſt, other new ones, &c. At the outmoſt extremity of each branch is to be ſeen a polypus. And as theſe branches are not all of a length, ſo neither is each polypus, as in the firſt manner, above at the group,

or

or at an eqnal diſtance from the undermoſt part of the ſtalk. Here rather polypuſes are found in all heights of the group or cluſter. Mr. profeſſor *Kaſtner* has found ſuch polypuſes in the water with ducks-meat. The ſtalk, which bears the whole group, and each branch thereof, is ſuſceptible of an extraordinary ſort of motion. Each ſuddenly contracts itſelf, upon being touched, upon moving the glaſs, wherein the whole group ſits; and ſometimes alſo, when there is no obſervable cauſe of any ſuch contraction. The ſtalk and the branches contract and ſhorten, ſo as to draw themſelves into circles, which then touch each other quite cloſe. Each branch may contract itſelf apart; though this happens but ſeldom. For, one branch alone contracting, commonly ſtrikes againſt another branch: and then inſtantly that other contracts with it. When the principal ſtalk, which carries the whole group or cluſter, contracts itſelf, all the other branches alſo of the group draw themſelves in; and the whole group locks cloſe. A moment after, the branches together with the ſtalk expand themſelves again, and again the whole group thereby acquires its wonted form. But when the group is pretty well grown, the ſtalk ceaſes to contract. Such a group or cluſter ariſes in the following manner. A ſingle polypus, which is ſeparated from the group or cluſter, ſwims about ſo long in the water, till it finds a fit body, whereon to ſettle. Then it has a ſtalk, no bigger than the polypus itſelf. In the ſpace of 24 hours

this ſtalk becomes eight or nine times as long as it was before. And then this ſtalk comes to be the principal ſtalk of a new group or cluſter. In about a day after, when the polypus has thus fixed itſelf, it divides in two. In 10 or 12 hours after, each of theſe two polypuſes divides into two others. And immediately after, they ſhoot out branches, and thus they ever remove farther aſunder. Only it is neceſſary to obſerve, that when two of theſe polypuſes are thus formed by the diviſion of the one, one is commonly far bigger than the other. This bigger one remains at the outmoſt extremity of the branch, at which it before was. But this branch lengthens, and then the other lets out a new branch, which appears to proceed from the firſt. The bigger of theſe polypuſes commonly divides ſooner than the other. And all we have hitherto ſaid is repeated for a number of different times. And thus a principal branch is formed, which is furniſhed with different ſide-branches. Theſe ſide-branches again come themſelves to be principal branches, with regard to thoſe, which again appear to ſpring out from them, when the polypuſes at their outmoſt extremities begin to divide themſelves. The polypuſes of a group or cluſter ſeparate not all at the ſame time from it. Thoſe neareſt the origin of the branch commonly ſeparate firſt. And each polypus, ſo ſeparated, fixes itſelf ſomewhere, ſo that each of them at laſt, if not reſtrained, forms a new group or cluſter. Theſe branches actually ariſe from the

polypuſes,

polypuſes and have their nouriſhment from them. For they directly ceaſe growing, when the polypuſes, that ſit at their extremities, are ſeparated therefrom either naturally, or by ſome accident. From the branches of the group or cluſter alſo ariſe certain round bodies or buttons, which in two or three days attain their full growth, and then ſeparate themſelves, and ſwim away therefrom, till they can ſettle on a body, which they commonly meet with in the water; on which they inſtantly faſten with a ſhort ſtalk. Theſe ſtalks are gradually lengthening for 24 hours. During this time, the round body turns almoſt oval. In a group or cluſter there are but few of theſe round bodies. Such a group increaſes, and the polypuſes multiply thereon, juſt as the polypuſes that ariſe from other polypuſes do.

§. 527. Some animals have no ſex, neither do they generate, as the common and working bees. And hence *Swammerdam* in his *Biblia naturæ*, c. 4. claſs 3. ſays, that we may conſider them as natural eunuchs. The males among bees carry viſible organs of generation on their bodies; as the internal horney bone of the penis, the penis, the teſticles, the *vaſa deferentia*, with their dilatations, the *veſiculæ ſeminales*, beſides ſome other parts. In the female are the *ovarium*, the oviducts, with their diviſions, the eggs, the two branches or horns of the *uterus*, through which the eggs ſhoot, the neck of the uterus, and the *glue-ſacculus*. Some parts the female has in common with the labouring bees; as the

ſting, its bladder of poiſon, its little tube, and the ſheath of the ſting. As theſe parts are wanting in the male; it appears, that the working bees come nearer to the nature of the female than of the male; and they only want the *ovarium.* Their only buſineſs is to feed the young bees, to build their huts or cells, and to provide both for themſelves and the other bees. None of which things either the female or the male does, the former only laying her eggs in the cells, and the latter impregnating them in the *ovarium.*

§. 528. From the blood of a great many animals is ſecreted in certain veſſels a liquor, which is ſo adapted for that purpoſe, as that an animal of this ſpecies may ariſe out of it. This matter is called the *ſeed* of an animal.

§. 529. The animals, that have ſexes, are either males only, or females only, or both together, that is *hermaphrodites.* In a female only is contained a certain organical matter or part, in which an animal may be formed and grow, when the ſeed of another animal is impelled into it. If this matter remains united with the female, till the young animal therein comes to its full maturity, it is called the *uterus* or womb. But if it may be ejected by the female, and yet remain adapted for the compleat formation of the animal, it is called an *egg.* A male only has neither womb nor eggs, but ſeed only.

§, 530. Among certain ſpecies of animals, the male and female generate without coition. Inſtances of

of this kind we have in many ſorts of fiſh. On the roes, diſcharged by the female, the milt of the male is barely ſquirted. To this *Swammerdam* in the place above quoted, claſs 3. adds, that thus too it holds with the *hemerobios* or *ephemeron*, the day-fly, whoſe female, in her flight through the air, lets her eggs ſhoot into the water, where they are ſought out by the male, and impregnated with his ſeed. The *hemerobios*, which *Swammerdum* deſcribes at large, cap. 1. has four wings, two very ſmall horns, ſix feet, and two very long protended hairy tails, and at the longeſt lives for five hours. It is found yearly about St. *John*'s day in the mouths of the *Rhine*, the *Meuſe*, the *Wahl*, the *Leck* and the *Yſel*. When the female is come forth out of the water, and has caſt her ſkin, ſhe plays for ſome time, by moving her wings in a curious manner, on the ſurface of the water, and flies in a conſtant ring over it, after which ſhe ſhoots her eggs into the water. And if now impregnated by the ſeed of the male, who has juſt aſcended too, in the manner aforeſaid, out of the water, and caſt a very tender ſkin, they ſink gradually down into the ſlime. Out of which in ſome time after comes forth a ſmall ſix-footed worm, which for three years wallows about in the mire, in order to aſſume a form, which it is to lay down again in five hours. *Swammerdam*, cap. 1. claſs 3. holds of bees, that the female is impregnated barely by the ſtrong odour or exhalation of the ejected male ſeed. His reaſons are the following. 1. The penis of the male

male bee is unfit for generation, partly as being imperforated; partly as on account of its form and position it cannot be introduced into the body of the female. And did this happen too, yet the penis could not convey the feed into the womb, as being difcharged by quite another way. Nor can the males ever find the female alone, being conftantly furrounded by the working bees. Further, experience teaches, that the feed of the male bees has fo penetrating a quality, that upon putting only feven or eight of them in a box, they fo taint it with the feminal exhalation, that one who never fmelt it, can fcarce believe how ftrong it is.

§. 531. Inftances of unconteftable hermaphrodites we have in fnails. Their copulation is defcribed by *Swammerdam*, clafs 1. cap. 9. The penis and uterus, naturally joined, adhere clofe together. For fome days before copulation the fnails gather together, and remain lying ftill by each other, and eating very little. They place themfelves fo, that neck and head ftand bolt upright. With the extremities of the rims or borders of their bodies they hold themfelves upright. In the neck the aperture of the organs of generation often opens, and again often fhuts. The fnails approach each other gradually, like two hands laid flat on each other, finger anfwering to finger. In this manner neck and head are upright, and directly over againft each other. Then appear the moft aftonifhing motions of both the heads and eight horns againft each other,

other, as can ſcarce be imagined. One might readily take theſe motions for an uninterrupted hugging and kiſſing. The horns move in ſo various a manner, that it is not eaſy to conceive, how they can have ſo many, and ſo different muſcles for the purpoſe. So ſoon as they have but in the leaſt touched each other with the horns, they quickly draw them in again, or move them upwards, downwards, or ſideways. And theſe motions are inceſſantly repeated. This play holds many times for three days. But now in order to mix or copulate duely, each of them moves his penis and at the ſame time the mouth of the uterus quite out of the body. And then the mixture or copulation happens, when the male organs twiſt round each other, that each ſnail with its penis may hit and impregnate the womb of the other.

Paſtor *Leſſer*, ſenior of the lutheran miniſtry at *Nordhauſen*, a man experienced in, and famous for his enquiries into natural curioſities, writes in his *Teſtaceo-theologia*, note p. 93. that oyſters, the *balani marini*, and rock-muſſels have ſomething quite extraordinary, as being not only hermaphrodites, but alſo without copulation with others of their ſpecies, bringing forth young out of themſelves; and thus each apart is man and wife; bridegroom and bride; dwelling-houſe and marriage-bed.

CHAP.

CHAP. II.

Of the Opinions about the Generation of Animals.

§. 532. HOW it happens, that two animals of a ſpecies, a male and a female, generate a third of their ſpecies, on this head various opinions have ariſen among philoſophers, of which M. *Buffon* in his *General hiſtory of nature*, T. 2. P. 1. c. 5. has given a circumſtantial hiſtory. In the moſt ancient ſyſtems they attempted to explain this generation from the mixture of the male and female ſeed. According to *Ariſtotle* the blood of the female, which is otherwiſe diſcharged monthly, is the only matter, from which the fruit or fœtus is formed and animated by the moving force of the male ſeed. But *Hippocrates*, who lived 50 or 60 years before him, imagined, each ſex, as well the female as the male, to have a fruitful ſeed; and the formation of the fruit or fœtus to happen in the following manner. The ſeeds were mixed at firſt in the uterus, and there condenſed by the natural heat of the female; the mixture received and drew the ſpirit from the warmth, and when all was filled therewith, the too warm ſpirit went off; but by the reſpiration of the pregnant females there was an acceſſion or ſupply of cold ſpirit. And thus the ingreſs of the cold ſpirit and the egreſs of the warm happened alter-

nately

nately in the mixture. On the ſurface of the mixture a pellicle was formed, which aſſumed a round form. And gradually another ſkin was formed. The menſes, which were now with-held, afforded ſufficient nouriſhment. And this blood, which was conveyed to the fruit or fœtus by the pregnant female, gradually condenſed to fleſh. And this formed itſelf, as it grew, gradually into members, and the ſpirit gave this fleſh the form. Each thing occupied its own place, the ſolid parts retired to the ſolid; the fluid, to the fluid, each thing ſeeking its like. Beſides this, *Hippocrates* taught, that each ſex had a twofold ſeed; one more ſtrong and active; another, leſs ſo. The mixture of the ſtrongeſt male ſeed with the ſtrongeſt female ſeed yielded a boy; and the mixture of the two weaker, a girl. The opinion of *Ariſtotle* was followed by the ſcholaſtick philoſophers; and that of *Hippocrates*, by *Galen* and almoſt all the phyſicians, till the eighteenth century.

§. 533. Afterwards they gave into the opinion, that all animals were produced from eggs. In the ſixteenth century *Fabricius ab Aquapendente*, a profeſſor of anatomy at *Paris*, undertook to form a ſyſtem of connected obſervations on the impregnation and evolution of a hen's egg; but thereby he arrived at no diſtinct explication of generation. In the ſame century *Aldrovandus* at *Bolognia*, his ſcholar *Volcher Royter*, city-phyſician at *Nuremberg*, and *Pariſanus*, the *Venetian* phyſician, made obſervations on

on eggs and their hatching, and gave defcriptions thereof. In the feventeenth century Dr. *William Harvey*, phyfician to king *Charles* the firft, wrote his *Exercitationes de generatione animalium*, after having for a long time made a feries of the neceffary obfervations on eggs, hinds and roes. He thence concluded, that all animals of the female fex had eggs, which were impregnated by the virtue of the male feed, without leaving in them any impreffion from it. According to *Harvey*'s opinion, the impregnation of the egg happens on the fmall part thereof, which appears like a fcar or *cicatrix*. He fays, all eggs had this *cicatrix*, whether impregnated or no: but it increafed, fo foon as the egg in the brooding obtained a proper degree of warmth. In twenty hours of brooding there appeared in the middle of the *cicatrix* a white point or fpeck, together with a variety of rings about it. In two days this fpeck appeared in form of a vefitle, on the fourth day an animated and beating point (*punctum faliens*) appeared in that place, which *Harvey* takes for the heart. In about 30 or 40 years after *Harvey*, the *Italian* phyfician *Malpighi* made new obfervations on eggs in the courfe of brooding, and in that cafe made ufe of magnifying glaffes, and he difcovered fuch things, as *Harvey* either had not obferved, or for want of his papers, moft of which he loft in the troubles of *Charles* the firft, he could not accurately recover their contents from his memory alone. *Malpighi* at firft made experiments with eggs without brooding, and faw,

that the *cicatrix* in the impregnated eggs was always bigger than in the unimpregnated: and the *punctum saliens*, which appeared to *Harvey* to be the heart, exhibited to him a bladder ſwimming in a liquor. In its middle, through its tranſparent pellicle he diſcovered the fruit, and thence concluded, that the chick was extant in the egg before brooding. In eggs, which the hen laid, without impregnation of the cock, he found near the middle point of the *cicatrix*, inſtead of a bladder, a round body, in which he could obſerve nothing formed, whether he viewed it unopened or opened. Then *Malphigi* turned his attention on eggs in the courſe of brooding, and diſcovered by his repeated obſervations the following ſteps and degrees in the growth of the included chick. After ſix hours of brooding the veſicle, which is formed by the *amnios*, is diſtinguiſhable in the middle of the *cicatrix*, and filled with a liquor, in whoſe middle one plainly ſees the head of the chick, hanging to the back bone, floating. In ſix hours after, one eaſily diſtinguiſhes the head, and the whirl-bones or *vertebræ* of the back bone. In ſix hours more, the head ſhews bigger, and the back bone longer. After twenty-four hours the head of the chick appears to have bent itſelf back, and the back bone to be ſtill more whitiſh. The *vertebræ* ſtand on both ſides of the middle of the back bone like little balls. Almoſt at this very time, the beginning of the wings is ſeen. Head, neck and breaſt lengthen themſelves. After thirty hours every

every thing is obſerved to be bigger, and the veſſels of the navel of a dark colour round the *amnios*. After thirty-eight hours the chick exhibits a pretty thick head, on which are ſeen three veſicles encompaſſed with ſkins, which in like manner cover the back bone, but yet ſuffer the *vertebræ* to be diſtinctly ſeen through. In and after this time the heart may be ſeen to beat. After two days, the head, which conſiſts of veſicles, is bent, the back bone lengthened, and the heart, which hangs out quite to the breaſt, beats three times ſucceſſively. For, the liquor, which it contains, is forced out of the vein through the auricle into the ventricles of the heart, and out of theſe into the arteries, and laſtly, into the umbilical veſſels. *Malpighi* ſeparated the chick from the white of the egg, and the motion of the heart continued ſtill for a whole day. After two days and fourteen hours the veins and arteries are ſeen, that go to the brain. After three days the body of the chick appears bent, and in the head one ſees, beſides the two eyes, five bladders full of liquor, which afterwards form the brain. One alſo ſees the firſt proceſſes of the legs and wings; the body begins to take fleſh, the balls of the eyes to be diſtinguiſhable, and the cryſtalline and vitreous humours to be already diſtinct. After the fourth day the veſicles of the brain approach nearer and nearer to each other, the eminences of the *vertebræ* turn ſtill bigger, and the wings and legs ever firmer, the more they are lengthened. The whole body is covered

vered with a ſmeary fleſh, the umbilical veſſels are ſeen to go out of the abdomen, the heart lies internally concealed, as the cavity of the breaſt is ſhut up with a very tender ſkin. After the fifth day and on the beginning of the ſixth the veſicles of the brain begin to be covered; the back bone divides into two parts, and begins to turn firm, and run along the back; the wings and legs are lengthened, and the feet extended, the abdomen is ſhut up and ſwells, and the liver is very diſtinctly ſeen; it is not yet red; but, inſtead of its whitiſh colour hitherto, it has acquired a dark; the heart beats in both its ventricles, the body of the chick is covered with the ſkin, and one ſtill diſtinguiſhes the ſpecks there where the feathers ariſe. On the ſeventh day the head is very big, the brain appears to be covered with its ſkins, the bill ſhews very diſtinct between both the eyes; wings and legs and feet have their perfect form, then the heart appears to conſiſt of two ventricles, which ſhew like a pair of bellows, in contact with each other, which at the upper part are united with the auricles themſelves: and one obſerves two motions, following each other, as well in the ventricles as alſo in the auricles of the heart, as if there were two ſeparate hearts. At the end of the ninth day the lungs appear. On the tenth the muſcles of the wings come in view, and the feathers ſtrike out. On the eleventh day one ſees, how the arteries, which at firſt were ſeparated from the heart, hang thereat, as the fingers at a hand; as then firſt the

the heart is perfectly formed and united into two ventricles. The remaining days throughout, all the parts turn gradually diſtincter and bigger, till on the one and twentieth day, when the chick breaks through its ſhell, after it has peeped. Whether in the females, that bring forth live young, eggs are really contained, experience has not hitherto ſufficiently diſcovered. *Steno*, formerly phyſician to *Ferdinand* II. grand duke of *Tuſcany*, and *de Graaf*, a *Dutch* phyſician, are the firſt, who attempted to diſcover theſe pretended eggs. In the *teſtes* of female animals are certain veſicles, containing a liquor, which on the fire curdles like the white of eggs. In like manner ſometimes a firm and yellow body is produced, which hangs at the *teſtes*, and projects, and gradually acquires the ſize of a cherry. *Malpighi* ſays, he has many times ſeen an egg of the ſize of a millet-grain in ſuch a yellow body. The veſicles, which are obſerved at all times, he takes not for any genuine eggs; and believes they ſerved for nothing but producing the yellow body, where the egg is to be formed. *Vallisnieri*, *Malpighi*'s ſcholar, has taken unſpeakable pains to find ſuch an egg, but always in vain. Notwithſtanding, he was fully of the opinion, that the egg lay concealed in the cavity of the ſaid yellow body; and that the ſpirit of the male ſeed, being aſcended to the *ovarium*, penetrated the egg, and gave motion to the fruit, which was already extant in this egg. *De Graaf*'s experiments miſled moſt naturaliſts ſo

ſo far, that they perſuaded themſelves, that the ſcars or *cicatrices*, to be met with in the *teſtes* of the female animal, were places, where eggs had lodged; and from the number of theſe *cicatrices* the number of the fruits or fœtus's was pretended to be ſhewn. But *Mery* a *French* ſurgeon, in the beginning of this century, ſhewed in the *teſtes* of a woman ſo great a number of *cicatrices*, that according to the ſyſtem of the eggs this woman muſt have had an uncommon degree of fruitfulneſs. Theſe difficulties excited the zeal of the other *French* anatomiſts, who ſtood up for the eggs, to take all imaginable pains to diſcover them. *Joſeph du Verney* cut away the *teſtes* from cows and ſheep, and maintained, that the veſicles were the eggs, and the yellow body on the *teſtes* he took for an accidental excreſcence, which he compared with the galls on oaks. *Littre* went ſo far as to affirm, that he had ſeen a well-formed fruit or fœtus in ſuch a veſicle, ſtill adhering to, and lodged in the innermoſt part of the *teſtes*; in which fruit he could perfectly well diſtinguiſh head and tail. But *Valliſnieri* found the opinion of both theſe anatomiſts not verified by the trials he himſelf had made. *Nuck*, a *Dutch* phyſician, opened a bitch three days after lining, drew out one of the *tubæ*, or ducts, which are cloſely connected with the *uterus*, and which may rear and apply themſelves to the female *teſtes* or *ovaria*, he put a ligature thereon in the middle, ſo that the whole upper part could have no communication with the under. And then he conveyed

veyed this *tuba* to its place and closed the wound. After twenty-one days, he opened it again, and found two young in the upper part, that is between the *testes* and the under ligature. In the under part of this *tuba* there was no young found. In the other *tuba*, on which no ligature was made, he found three young, which had the ordinary position. This he gives as a proof, that the fruit did not arise from the male seed, but was rather pre-existent in the egg of the female. But to this M. *Buffon* objects, that did even this experiment answer at all times, it would only follow, that the fruit or fœtus may be formed as well in the upper as in the under parts of the *tubæ*.

§. 534. Whilst it was attempting to establish the system of the eggs, there arose another at the same time, from the two *Dutchmen*, *Leewenhoeck* and *Hartsoeker* discovering *animalcula* in the seed of the male. *Leewenhoeck* describes his observations in the 18th, 23d, 30th, 31st, 41st, 57th, 64th, 113th, 116th, 117th, 142d, and 143d epistles, as also in the tome, with the title atop the pages, *Anatomia* and *Contemplationes*, first part, from p. 49. to p. 51. and part 2d, from p. 149. to p. 161. On the contrary, the *ovaria* and eggs, ascribed to animals, bringing forth live young, he, in the 23d and 30th epistles, and in his *Experimenta* and *Contemplationes*, epist. 57. p. 26 and 27. and in epist. 81. p. 400 and 401. holds for an idle fiction. These *animalcula* in the different species of animals are of different forms; but all oblong and

 tender,

tender, and without any diſtinguiſhable members, and moving very quick and in all manner of directions. Their number is ſo great, that the ſeed of a male animal ſeems intirely to conſiſt of them. In the ſeed of a frog *Leewenhoeck* obſerved ſo great a number, that p. 52 of the *Anatomia* and *Contemplationes* he believes, that in one copulation about 10,000 might be reckoned to one frog egg. In the ſeed of cocks, as he relates, p. 30. of his *Experimenta* and *Contemplationes*, he found theſe *animalcula* ſo minute, that the compaſs of a ſmall grain of ſand could contain 50,000 of them. In the ſecond part of the tome with the title *Anatomia* and *Contemplationes*, he ſhews p. 9, 10 and 11. by a calculation, that the milt of a ſingle *cabeliau*, a ſort of cod fiſh called in *Latin Aſſellus major*, contains above ten times more *animalcula* than there are men at one time upon the face of the earth. His calculation is as follows: in *Holland* he ſuppoſes the number of the inhabitants to be one million, and the inhabited part of the earth to be 13,385 times bigger than *Holland*. This preſuppoſed, the number of the inhabitants of the whole earth are upwards of thirteen thouſand millions. Whereas in the milt of a ſingle *cabeliau* are contained to the number of a hundred and fifty thouſand millions of living *animalcula*. For, they are ſo minute, that 10,000 of them fill no greater a ſpace than that of a ſmall grain of ſand, whoſe diameter is the hundredth part of an inch. If the length of an inch contains 100 ſuch grains of ſand, a million of them goes to the

ſpace of a cubick inch. So that ten thouſand millions of *animalcula* from the milt of a *cabeliau* are contained in a cubick inch. But its whole milt contains a ſpace of fifteen ſuch inches. Now if fifteen times ten thouſand makes 150,000, the number above aſſigned of living *animalcula* is juſt. Now as in the animals of the female ſex no ſuch worms are to be diſcovered; ſeveral naturaliſts and phyſicians have with *Leewenhoeck* gone into the opinion, that the generation of animals might be explained from ſuch *animalcula*. *Leewenhoeck* denies eggs to thoſe animals, which bring forth live young. According to his opinion there is nothing further neceſſary to the generation of ſuch an animal, than that one or more of the *animalcula*, which in the copulation came into the *uterus*, ſhould happen into ſuch circumſtances, as there to find proper nouriſhment for its growth. But from this opinion departed the other enquirers into generation, as ſtanding up not only for worms in the animals of the male ſex, but alſo for eggs in thoſe with wombs. They held, that the *animalcula* in the act of copulation reached not only to the *uterus*, but alſo aſcended through the *tubæ* of the womb, and crept into the eggs of the females. They further imagined, that theſe eggs were by the growth of the animals, now included in them, ſeparated from the *ovarium*, and conveyed into the womb by one of its *tubæ*, and that the included *animalcula* by the affluent nouriſhment gradually attain a diſtinguiſhable magnitude of their preformed members, only hitherto

lying

lying concealed. And thus all men and beafts, according to this opinion, were as worms, before their generation and birth, lodged in the feed of the male.

§. 535. Againft this fyftem of the *animalcula*, M. *Lyonnet* in his remarks on M. *Leffer*'s *Theologie des infectes* tranflated into *French* from the *German*, and 1742 printed at the *Hague*, has ftarted confiderable objections, which M. *Chriftlob Mylius* has with much attention examined in an epiftle on the *animalcula*, publifhed at *Hamburg* in 1746. M. *Buffon* in the place above quoted declares himfelf as well againft the fyftem of the *animalcula*, as alfo againft that of the eggs, and ftarts objections partly againft each in particular, partly againft both together and in general. In fo far as the defenders of thefe fyftems affume this at the fame time, that the firft animal of each fpecies, as according to the doctrine of the *animalcula* the firft man, and according to the doctrine of the eggs the firft woman, contained in them their whole pofterity; he objects, that they fet up an infinite progreffion, in which the underftanding is bewildered and loft. For, fays he, a feminal worm is more than a thoufand million of times lefs than a man. And thus if we affume unity for the fize of a man, that of a feminal worm is no otherwife to be expreffed than by the fraction $\frac{1}{10000000000}$, that is, by a number with ten figures. Now as the man is to the feminal worm of the firft generation, as this worm is to the feminal worm of the fecond; fo the magnitude, or rather the minutenefs of this fecond

ſeminal worm can be no otherwiſe expreſſed than by a number of nineteen figures; and for the ſame reaſon the minuteneſs of the ſeminal worm of the third generation, only by a number of eight and twenty figures; of the fourth generation, by ſeven and thirty; of the fifth, by ſix and forty; and of the ſixth, by five and fifty figures. In order to be able to form to oneſelf a notion of the degree of minuteneſs, which is expreſſed by this fraction, we will aſſume the dimenſion of the whole ſphere of the world from the ſun to *Saturn*, and exhibit the ſun about a million of times bigger than the earth, and diſtant from *Saturn* about a thouſand of the ſun's diameters. And we will find, that only 45 figures are neceſſary to expreſs the number of cubick lines, which are contained in this ſphere. And if we divide each cubick line into a thouſand million atoms, their number may be expreſſed by 54 figures. And conſequently the man, againſt the ſeminal worm of the ſixth generation, would be much bigger than is the ſphere of the world againſt the ſmalleſt particle of duſt, diſtinguiſhable only by the magnifying glaſs. And what would be the reſult, did we carry on this calculation to the tenth generation only? The minuteneſs would be ſo conſiderable, as in no manner to be conceivable. This calculation may in like manner be applied to the eggs. The ſecond difficulty M. *Buffon* finds in the unequal number of the ſexes. In the ſyſtem of the eggs, ſays he, the firſt woman contained male and female eggs, among which the male contained no more than one generation

generation of the male ſex; on the contrary, the female, thouſands of generations of male and female eggs. At one time and in one woman we always find a certain number of eggs, ſuſceptible of an infinite evolution; whereas there is likewiſe another number of eggs therewith, ſuſceptible of a ſingle evolution only. Juſt ſo in the other ſyſtem, the firſt man contained male and female ſeminal worms. The female contained no others. But all the male contained others, partly male, partly female, in an infinite progreſſion. And thus there muſt be found in one man and at one time *animalcula*, undergoing an infinite evolution; and others, a ſingle evolution only. In theſe things, thus preſuppoſed, is there the leaſt degree of probability? The third difficulty, ſays he, reſts on the likeneſs of the children to the father or the mother, or alſo to both alike, and the diſtinguiſhable characters of both ſpecies in mules, or animals, that derive from parents of one and the ſame genus, but of a twofold ſpecies. If the ſeminal worm is the fruit of the father, how can the child be like the mother? If the fruit is pre-exiſtent in the egg of the mother, how can a child reſemble the father? If the ſeminal worm of a horſe, or the egg of a ſhe aſs contains the fruit; how can the mule at the ſame time partake of the nature of the horſe and ſhe aſs?

§. 536. The caſe being thus, M. *Buffon* has brought up a new ſyſtem, in which he has partly renewed the ancient doctrine of *Hippocrates*, partly added

added a peculiar and ingenious thought of his own thereto: his thoughts thereon he has fully propounded in the cited tome 2. but his doctrine comes to this. The nourishment, the growth, and the generation of an animal arise from one and the same matter. This consists in organical animated parts, which are extant in the corporeal world in vast quantities, and mixed together now in this, again in that manner, and again separated asunder, and yet notwithstanding continuing constant and unchangeable. In the nourishment, which an animal takes in, is contained a great number of such organical particles. These at last come into the chyle, and with this into the blood. The chyle is along with the blood conveyed to all the parts of the body, and by its circulation purged from all unorganical particles. The organical remain behind, as in effect they resemble the blood, and thus, in force or virtue of kindred, are retained. As afterwards, the whole mass of the blood goes repeatedly thro' the body, each part of the body attracts to itself the particles, that are likest to it, and lets those go, that are least so. These organical particles penetrate quite through each part of the body in all directions and points. Hereby the animal is preserved in its duration, or nourished. But it also grows, when all its parts are so extended by the pervading matter in length, breadth and thickness, that each part in its growing state, as well retains the former order among its particles, as also remains in the former proportion

proportion with the other particles of the body. M. *Buffon* reprefents to himfelf as well an animal body, as alfo each member, and each part thereof, as an internal form, which takes the matter, coming to it, only in the order, which arifes from the pofition of its parts. The organical parts of this nourifhing, and growth-promoting matter, are extremely various. Each part of an animal body affumes only the fort, that are beft adapted, and thus fimilar to it. If the parts of the animal body have taken in all, that they well can, of this organical matter; the over part, which they cannot contain and keep, is feparated from them, and conveyed to a place, allotted for it. As now this feparation happens from all the organical parts of the animal, pure organical particles, like the organical particles of the animal body, collect and unite themfelves in the faid place. In thefe feparated and collected organical parts confifts the feed; which contains all particles, that are neceffary to form an organical corpufcle, refembling the animal body, of whofe collective parts the feed is an extract. This feed is to be met with not only in the male, but alfo in the female animals. For the repofitory of the female feed in thofe animals, which have wombs, M. *Buffon* allots the *cavity of the tranfparent body* in the part, where otherwife the egg is looked for; and defcribes in the fixth chapter, from the 36th to the 42d experiment, the experiments, whereby he was confirmed in thefe his thoughts. The firft experiment

ment he made with a bitch, opened alive, that had been proud for four or five days, but to which no dog had yet approached. But in order to have a counter object, which he might compare with the female liquor, he previously observed the seed of a dog, and saw therein corpuscles in motion and with tails, which are otherwise usually called seminal *animalcula*. The glandular body in the one *ovarium* of the bitch was as big as a pea. He viewed the liquor, contained therein, with the magnifying glass, and instantly discovered corpuscles, perfectly resembling those, he had seen in the seed of the dog. Mr. *Needham* and M. *Daubenton*, to whom he shewed these corpuscles, were so astonished at this resemblance, that they suspected, some of the seed of the dog might perhaps have been left lying on the plate. Mr. *Needham* therefore took another quite clean plate, and did some liquor thereon from the glandular body: but by the magnifying glass observed just the like corpuscles in motion, as appear in the male seed. This they saw at different times and in different drops. Fourteen days after, M. *Buffon* opened another bitch, that had been proud for seven or eight days before, without any dog coming near her. He found on each *ovarium* a perfectly ripe glandular body, and in both these bodies liquors, in which the corpuscles in motion, and with tails, were seen as plentiful as in the male seed. He opened the *tubæ* of the womb lengthwise, and found therein only so much liquor, as could be taken

up

up with a tooth-pick. By the magnifying glaſs he obſerved therein pure active globules, perfectly reſembling the globules, which he had before obſerved in the liquor of the glandular body, and moving juſt in the ſame manner. This ſeed from the *tuba* he mixed with the ſeed from a dog, and ſaw in the mixture ever one and the ſame corpuſcles, and ever in one and the ſame motion. Theſe corpuſcles, which on account of their motion have been taken for *animalcula* in the male ſeed, M. *Buffon* takes in both ſeeds for nothing other, but an aggregate of organical particles, ſeparated from all parts of an animal. For, in the firſt place, ſays he in the 8th chapter, theſe ſeminal *machinulæ* ever go on of themſelves, without ſtopping; and when they once ſtop, they then ever lie ſtock ſtill. I aſk, whether ſo inceſſant a motion be the ordinary motion of animals? Secondly, theſe corpuſcles change their form every moment, have no peculiar diſtinguiſhable member, and their tail appears to be only a part, not appertaining to them. The firſt, *Leewenhoeck* obſerved in the *animalcula* of dogs. The ſecond may in like manner be ſeen from his experiments; he having found in the ſeed of a cock many very minute globules, as alſo many flat oval forms, which moved like the other corpuſcles with tails. The tail of this corpuſcle M. *Buffon* holds only for a matter, which a corpuſcle in motion draws after it in the manner of a thread, and which after a certain period quite diſappears. Thirdly, one obſerves threads

threads in the ſeminal liquor, that lengthen themſelves, and appear to grow in the manner of plants, and afterwards ſwelling, produce theſe bodies in motion. Fourthly, we find ſuch bodies in fleſh, in buds, and other parts of plants. M. *Buffon* put fleſh of different animals, and above twenty different ſorts of ſeeds, on which water had been poured, in very cloſe ſtopped glaſs bottles, in which the water ſtood about half an inch high over theſe matters. In four or five days he obſerved as well in the water on the fleſh, as alſo in that on the ſeeds, juſt ſuch organical particles in motion, as are to be met with in the ſeed of animals. Mr. *Needham* left jelly of veal, and other roaſted fleſh, lying for ſome days in very carefully ſtopped bottles, and then ſhewed M. *Buffon* by the magnifying glaſs a number of corpuſcles in motion in this mixture, reſembling the corpuſcles, to be met with in the ſeed of animals at the time, when they no longer have any threads or tails.

Now from this M. *Buffon* concludes, that the corpuſcles, which move in the ſeed, were indeed animated ſubſtances, but yet only an intermediate ſort between plants and animals. As to the female animals, without any womb, but only with eggs, which are ejected or laid; M. *Buffon* in chap. 8. ſays, that in each egg a ſmall drop of the fruitful female ſeed was contained in that part, which is called the *cicatrix*. This fruitful drop, ſays he, collects itſelf, according to *Malpighi*'s remark, under the form of a ſmall *mola*, or falſe conception, when no

no male feed comes to it. Both feeds, the male and female, contain all parts, common to both fexes. But befides thefe, the male feed contains only the parts diftinguifhing the male; and in the female are found only thofe diftinguifhing the female fex. And in this particular M. *Buffon* thus departs from the opinion of *Hippocrates* (§. 532). From the mixture of both feeds M. *Buffon* at length explains, chap. 10. the formation of the fruit or fœtus in the following manner. If both liquors are mixed, fays he, the activity of the organical particles of the one will be brought into a ftate of reft by the oppofite action of the particles of the other. And thus each particle lofes its motion, and remains in the place, which fuits thereto, or is fimilar to that place, which it had in the body of the animal. Thus, for inftance, all particles, which were feparated from the head of the animal, are brought together into one arrangement, fimilar to that, in which they were actually feparated. Thofe particles, which derive from the fpine, unite together in that order, which the ftructure and pofition of the *vertebræ* require. And thus it holds of all the other parts of the body. And thus thefe particles form a fmall organical fubftance, perfectly fimilar to the animal, of which they are an extract. This mixture of organical particles of both forts of animals contains fimilar and diffimilar parts. The fimilar are thofe, drawn from the members, which both fexes have in common; and the diffimilar, thofe

derived

derived from the parts, which diſtinguiſh the male from the female. And thus there are in this mixture as many organical parts again, adapted to form a head, a heart, or any other part, in common to both ſexes, as contribute to form the organs of generation. But yet the organical particles only of the parts, common to both ſexes, can act on each other, without being brought into confuſion, as if they were the extract of one individual body. The diſſimilar particles, as the organical particles of the organs of generation cannot act on each other, nor intimately mix, as not being mutually ſimilar. The organical particles, which derive from the organs of generation, firſt take firm footing, and ſerve for the baſis and ſupport to the other particles. For, as theſe parts alone differ from the others; they may all have a different action, act againſt the others, and reſtrain their motion. Thus the organical particles, which in the mixture derive from the organs of generation of the man, will be the only ones, which may ſerve for the ground and ſupport to the organical parts, deriving from all parts of the female body: and the organical particles, which in this mixture exhibit the organs of generation of the woman, may ſerve for the ground and ſupport to thoſe, deriving from all parts of the male body. But as to the reſt, M. *Buffon* ſays, how it is only probable to him, that the parts of generation ſerve for the point of union to the reſt, as in the common parts he ſaw no cauſe of preference. He ſaid, the

the organical particles ſettle and unite, when they have loſt their motion. This to him appears therefore certain, as in the male and female ſeeds many corpuſcles are ſeen in motion, on viewing each apart; but on the contrary, a minute, and quite immoveable body only which muſt be put into motion by the warmth, is obſervable, on viewing what ariſes from the mixture of both active liquors. For, the chick in the middle of the *cicatrix*, before brooding, has no motion at all: alſo in twenty-four hours after, there is none to be obſerved without a magnifying glaſs. The firſt day there is a white ſlimy ſubſtance only, which from the ſecond day acquires ſome degree of firmneſs, and gradually increaſes by a ſort of life, reſembling the vegetative. Its motion is very ſlow, and by no means reſembles the quick motion of the organical particles in the ſeed. Beſides this, I have had ground to affirm, ſays he, that this motion was fully baulked, and the activity of the organical particles brought to a full ſtop. For, on laying up an egg, without giving it the neceſſary degree of warmth for brooding, the fruit or fœtus, perfectly formed therein, remains motionleſs; and the organical particles, of which it conſiſts, lie thus without motion, without being able of themſelves to give motion and life to the fruit, ariſing from their union. And thus after the particles have loſt their motion, have ſettled and arranged themſelves, an external power, as the warmth, which rarifies the juices, and forces them

to a circulation, muſt give this animal body the ability of unfolding itſelf. When the number of the male organical particles predominates in the mixture, the fruit or fœtus is male; but if there are more female parts, the fruit is female. The child is like the father or the mother, according as theſe organical particles are differently combined together, that is, according as, in the mixture of both liquors, they are in this or in that proportion.

§. 537. In like manner M. *Buffon* holds each animal, that has no diſtinction of ſexes, and yet can produce its like; and each plant, for an internal form, whoſe figure remains unchangeable, but whoſe dimenſions and ſize may increaſe in a due proportion of the parts among themſelves. He even derives this growth hence; viz. that each part of a plant, and of a ſexleſs animal, are intimately pervaded by the organical or formed and living parts, and receives ſuch ſimilar parts as are moſt adapted. At length he even explains the generation of ſuch an animal and of a plant, hereby; viz. that the overplus of the organical particles, which can be no longer received by the parts of the animal and the plant, comes then to certain places in animals and plants allotted for it; and that from the union of theſe particles, become ſimilar to the parts of an animal and a plant, ſuch an animal and ſuch a plant is at firſt formed

CHAP.

CHAP. III.

Thoughts on the Opinions about Generation.

§. 538. SO different as the hitherto deſcribed ſyſtems of the generation of an animal, ariſing from two of a ſpecies, are from each other; ſo they notwithſtanding all coincide in this, viz. that they always make the male ſeed indiſpenſably neceſſary thereto. But what it ſhould contribute, is the queſtion. *Ariſtotle* barely attributes a force to it, whereby the matter of the fruit, which is contained only in the female blood, is brought into motion, and a juſt arrangement (§. 532). But he adduces nothing to eſtabliſh his opinion. As *Ariſtotle* goes no further for the matter of the fruit or fœtus than the female blood; ſo *Harvey*, *Malpighi*, and their followers would lodge it in the eggs, and in like manner aſcribe nothing further to the male ſeed, than a force, by which the fruit in the egg is put into motion and animated. But have we neither inconteſtable experience, that female animals, which bring forth live young, have actually eggs; nor even marks and characters, from which to diſcover, that in an egg, before impregnation, the full matter for the fruit or fœtus is contained. Whether the corpuſcles to be met with in the male ſeed, which move with extraordinary quickneſs, are to be ranked among animals, is what, indeed, M. *Buffon*

calls in queſtion, but yet he ranks them above vegetables. His grounds (§. 536) are not however ſufficient to exclude them the animal kingdom. Muſt an animated corpuſcle be therefore no animal, becauſe it is in a conſtant motion? Does it then belong to the eſſence of an animal, that it muſt needs ſhift its ſtates of motion and reſt? And even the motion of the animated ſeed-corpuſcles is not uniform, as is perhaps that of a body, which moves only by an external cauſe, ever ſolliciting it to one direction. The ſeminal *machinulæ* go now in this, again in that direction, without being impelled or forced by an external cauſe, and move in the manner of fiſh. That they have no diſtinguiſhable organs, that they change their figure, that the threads grow in the manner of vegetables, all this, I ſay, ſerves as little to exclude them the number of animals, as tadpoles. That ſuch animated bodies are alſo found in ſoaked fleſh and ſoaked plants, ſhews nothing more than that they are not to be met with in the ſeed only. Dr. *Haller* in the preface to the ſecond part of the *General hiſtory of nature*, tranſlated into *German*, relates, that a perſon, experienced in the uſe of magnifying glaſſes, affirmed to him, that he had obſerved in the ſeminal *animalcula* all the ſigns of life; M. *Needham* himſelf allowed the ſeminal worms the privileges of life and ſpontaneous motion; and two experienced virtuoſi in inſects had, after repeating *Buffon*'s experiments, even reclaimed theſe worms back to the claſs of animals. But it is a different

queſtion,

queſtion, whether the ſeminal *animalcula* are of a ſpecies with the animals, in whoſe ſeeds they lodge, and conſequently young men in the male ſeed of men, the ſtructure of whoſe organs lies only yet concealed? To this we can hitherto anſwer neither in the affirmative nor in the negative, as we have no proper grounds either for the one, or for the other. M. *Buffon* with *Hippocrates* (§. 532). aſcribes in his ſyſtem a ſeed to both ſexes, and holds it for a ſummary of all organical particles, ſimilar to the organical parts of the animal, from which they are ſeparated (§. 536); and in chap. 8. ſurmiſes, that thoſe organical particles are perhaps what appear in the ſeed under the form of ſeminal *animalcula*. But as to the female, Dr. *Haller*, in the preface above quoted, makes the following objections. He queſtions not the experience, in which M. *Buffon* had found the liquor in the yellow body, or yellow gland, full of particles in motion. But then Dr. *Haller* ſays, that this is what this juice has in common with all human juices, even fleſh-broth itſelf containing ſuch living ſubſtances. That the yellow gland itſelf afforded a very ſtrong reaſon againſt M. *Buffon*. That the man had his *teſtes* from his birth, that they were mature, when he performed the act of copulation, and that the impregnating liquor, he diſcharged towards the great work of generation, was ready and prepared in the *teſtes*, previouſly fitted for it. But that the woman, and particularly the young beauties, had no yellow gland. That in women, who died without being impregnated, there never

was found a yellow gland. That when a young, hale and fruitful woman joins in copulation for the first time, ſhe is yet without this organ of the pretended ſeed. How then could ſhe have the ſeed, that is firſt to be collected in this organ? That this yellow gland was not the cauſe, but the conſequence of the impregnation, and aroſe firſt in a woman after a ſucceſsful copulation, laſted for ſome time after child-bed, and diſappeared gradually, and was never replaced by another like gland, if not impregnated again anew. I have, adds Dr. *Haller*, without prejudice and deſign, opened many hundred old and young women, and never above ten times found the yellow body, and always in women dying pregnant, lying in, or ſoon after child-bed. And the anatomiſts perhaps are not common, that have ſeen this yellow gland ten times in the man. Againſt the formation of the animated ſeminal particles, againſt the ſimilitude they are to have with the parts of the animal, in whoſe ſeed they are lodged, and againſt the origin of the fruit or fœtus therefrom, Dr. *Haller* ſtarts the following doubts and objections. The ſeminal particles according to *Buffon*'s ſyſtem are to be formed in the organical parts of the parents as in moulds and models. But, aſks Dr. *Haller*, can the matter, which forces into the organical parts of the parents, aſſume another form, than that of the intermediate ſpaces of the nouriſhing parts, between which it was lodged, and from which its own overplus had expelled it? Do ſuch elementary interſtices conſtitute the perſonal form of a man?

The

The particles of the ſeed are to be copies of the organical parts of the parents. Dr. *Haller* oppoſes to this, that no one man reſembles another in internal ſtructure, and conſequently no child his father in that reſpect. For proof, what follows is adduced. Dr. *Haller* ſays, never were two men ſeen, in whom all the nerves, all the arteries, all the returning veſſels, or veins, and even the muſcles and bones did not infinitely differ from each other. After deſcribing fifty times the arteries of the arm, the head or the heart, I found theſe fifty deſcriptions all unlike. And it gives me the greateſt trouble imaginable to reduce the greateſt part to a general coincident account. The diverſity, eſpecially in the nerves and the veins, is ſo infinite, that ſcarce any deſcription of them can be brought to bear. Not only the ſize of the branches, their angles, their poſitions, their diviſions, the places of the valves, and the exit of the branches differ, but even the number of their parts is never one and the ſame. The large branches are often, the middling always, and the leſs altogether on both ſides in the ſame body conſtantly unlike each other. And the child is thus no copy of the father. How could it otherwiſe differ ſo much from the father in its ſtructure; and what is ſtill more, how could it have parts, that the father has not? An anatomiſt knows well, that thouſands, and millions, nay thouſands of millions of veſſels are wanting in the grown and generating man, that are extant in the embryo. It has large umbilical arteries, an urinary

duct or *urachus*, an umbilical vein, and a *foramen ovale*, a pectoral gland, the *thymus*, and a number of other parts, which the father has not; and a double row of teeth against a single. A *Hottentot* with only one testicle; a *Swiss*, who has one of his testicles cut out in his childhood, long before, according to M. *Buffon*, the superfluous parts of the grown man are remanded back, begets an entire man with two testicles. A man also that loses a hand, a leg, an eye, begets a compleat son. Here indeed M. *Buffon* might ascribe the recruited arm and eye to the mother, but the testicles he cannot. The females, that are carefully kept and locked up with one single pug-dog, having, as little as the sire, any ears, bring forth young with a compleat set of ears. Do then young horses want the scoop-teeth, which the stallion and mare have long since shed? So that thus the child is not the copy of his father. The copies of the organical parts of the parents are what a child is to consist of, on both seeds being mixed together. Then Dr. *Haller* adds; but these formed parts float about without any order in the fluid seed; and M. *Buffon* has hitherto pointed out no cause, that should bring them into order, that should unite the particles of the eyes of the father with the particles of the eyes of the mother; and in particular those of the right side with those of the right side, and of the left with the left, and of the pupil with the pupil, and those of the *retina* with their fellows; that should direct the particles of the ear to their proper place and distance from the eye;

that

that ſhould in the juſteſt manner meaſure out the poſition and proportion of all the parts. There is wanting an architect to diſpoſe the many ſingle copies of the different parts of the large arteries in a proper arrangement according to the length of the body; and in a word, to conſtruct the divided, microſpical parts of the parent bodies according to the wonderful plan of a human body; ever to prevent an eye from being in the knee, or an ear on the forehead, or a toe from growing on the hand, or a finger on the foot, as in the ſhooting of ſalts and cryſtals innumerable unformed and diſplaced tacks or ſhoots are every moment to be found. M. *Buffon* here needs a force, which examines, chooſes, has an end in view, which againſt all the laws of a blind combination always and infallibly caſts a like throw. For, moſt animals conceive on the firſt copulation, and bring forth always regular animals, againſt the number of which, monſters happen ſo rarely, that according to the rules of calculation they may go for nothing.

§. 539. In ſuch great darkneſs therefore our underſtanding finds itſelf involved, when it would ſhew, what is the male ſeed, and what it contributes to generation! Was there neither in the eggs, nor in the female animals with wombs, any thing organical; we might reaſonably adopt the ſyſtem of the ſeminal *animalcula*; which may alſo be ſufficiently defended againſt the objections of M. *Buffon* (§. 535.), when inſtead of the firſt man containing all his poſterity, we conſider the *animalcula*, formed

formed in ſmall, as diſperſed all over the different bodies in and upon and above the earth. For, finding no formed matter at all in the female animals, why ſhould we then conſider the *animalcula* in the male ſeed as inſects and uſeleſs vermin; and on the contrary look upon the remaining matter of the male ſeed, in which nothing animated is found, more adapted for the formation of the fœtus? But if in the eggs and female teſticles ſuch animated corpuſcles are contained, as are met with in the male ſeed; it does not appear, how the generation of an animal can be explained thereby. For, if theſe corpuſcles in the animals of both ſexes are already animals *ſui generis*; how do they arrive to growth and to evolution, when coming together from both ſexes? Of two is there to be made one? How can one repreſent this to himſelf as poſſible? Is each time only a ſingle animal to be the fœtus? The fœtus is either male or female. An *animalculum*, that affords a male fœtus, may ariſe from the male ſeed; and an *animalculum*, that is to be a female fœtus, be contained in the female. But then what is the reaſon, that an *animalculum* from the female ſeed never turns to a growing fœtus, unleſs the *animalcula* of the male ſeed concur; whereas the female animal always yields nouriſhment and growth to the fœtus, either in the womb, or in an egg? Is one ſeminal *animalculum* to have the force of impelling another to the place, where it is to find the proper nouriſhment for its evolution?

From

From which ſeed is the impelling *animalculum* to be? If the animated corpuſcles in both ſeeds, according to *Buffon*'s opinion, are copies only of thoſe particles, of which the organs of the generating animals conſiſt, how can a third of the very ſame ſpecies be put together of two organical particles of one and the ſame ſpecies? For inſtance, how could the copies, which are to derive from the heads of *Cicero* and his *Terentia*, have been at one time able to unite into a head, which is adapted to young *Cicero*; and at another, into a head, fitted only for young *Tullia?* If therefore the male and female animals have in the liquors of their organs of generation, corpuſcles formed and animated of one and the ſame ſpecies, we cannot adopt and maintain either *Buffon*'s ſyſtem, or that, by which *Leewenhoeck* and others would derive the generation of animals from the *animalcula* of the male ſeed.

§. 540. And thus the ſyſtem of the eggs appears to gain a preference, which the objections againſt it (§. 538.) cannot affect. That in eggs, to which no male ſeed is derived, hitherto no ſigns of a matter for the fœtus are diſcovered, is far from being a ſufficient ground to deny ſuch matter. The fruit or fœtus may, on account of its minuteneſs, be undiſtinguiſhable. In how many grains of ſeed is not the contained plant undiſtinguiſhable for the very ſame reaſon! If therefore in the female animals, which bring forth live young, ſuch eggs were to be diſtinguiſhed, as are laid by other animals; it would

be far more probable to affirm, that the ſtructure of the animals, ariſing by generation, was contained in the eggs, than to give out either the *animalcula* in the male ſeed for the fœtus, or to derive generation from the mixture of formed particles in both ſeeds. But then muſt the matter, in which a fœtus, formed in little, or miniature, is included, be fully of the ſpecies, of which the laid eggs are ? When we repreſent to ourſelves an egg in general, as a round corpuſcle, in which a formed fœtus lies concealed, which, by the ſprinkling of the male ſeed, acquires its firſt growth ; we may affirm, that the eggs, which are laid by certain animals, are only a ſpecies of eggs. If we abſtain from the opinion, that among all the ſpecies of animals, the firſt female contained in her eggs her whole poſterity, M. *Buffon*'s objections (§. 535.) cannot affect us.

CHAP. IV.

Of the Generation of PLANTS.

§. 541. THE fruitful ſeed of a plant conſiſts of a ſhell, and an inner pellicle and of the fleſhy or pulpy part, and of an embryo-plant or *plantula ſeminalis.* And thus it coincides with an egg, which in like manner has a ſhell, and underneath, a tender pellicle or film, and the white and yolk, like the fleſhy part of the ſeed. And hence ſome of the ancient philoſophers held the ſeed of a plant for an egg. And therefore baron *Wolfius*, in his *Rational*

thoughts

thoughts on the uſe of the parts in men, beaſts and plants, §. 263. calls the ſeed an expounder of the egg, and this an expounder of that. The plantule contained therein is the principal part, as from it the future plant grows. It conſiſts of three parts, moſt diſtinguiſhable in beans, and in the kernel of fruits; of the radicle, which projects over the fleſhy part, of a pair of little leaves or blades, generally called the heart-blades, and of an eye, ſtanding in the middle between.

§. 542. Without bloſſom or flower no ſeed ariſes. And thus in the enquiry, how the ſeed is generated, and a plant may become fruitful, the nature and ſtructure of the bloſſom or flower are to be conſidered. Bloſſoms are of three ſorts, male, female, and hermaphrodite. The male bloſſom or flower has in its hulls and ſkins certain filaments, or *ſtamina*, which bear ſeed-repoſitories or *antheræ*, which moſtly conſiſt of two little ſhells, rolled up together, between whoſe *fibrillæ* a duſt is ſeparated, which, on the unfolding of the little ſhells ſtrews and diſſipates itſelf. The female bloſſom or flower is diſtinguiſhable by the piſtil, which conſiſts of the *ovarium* and the ſtyle. The *ovarium*, which contains the form of the future fruit, has in the middle of the flower-cup or *calix* a cloſe connection with a little body, which often appears like a little pillar, or alſo has another form, and many times called the cake or *placenta*. The ſtyle has ſeveral forms, and is often like a filament, and goes either to the centre of the *ovarium*,

or

or between what are called the *ovula*, or little eggs, to the *placenta*. The ſtyle is either one, or many fold. The one fold or ſingle divides in its progreſs into its different parts, uſually called the tubes of the ſtyle. Many ſtyles have an apparent cavity, but in many others it lies concealed. The hermaphrodite flowers have *ſtamina*, and a piſtil at the ſame time. The deſcription of theſe three ſorts is taken from M. *Ludwig*'s diſputation, in which he has in a conciſe and diſtinct manner treated on the ſexes of plants.

§. 543. According to theſe three ſorts of flowers, plants themſelves are thus divided into male, female, and hermaphrodite. Thus for inſtance, among the ſtalks of hemp, the maſtix, turpentine, palm and mulberry trees, ſome are of the male, others of the female ſex. Inſtances of hermaphrodite plants are gourds, haſel trees, cypreſſes, alders, oaks, and many others, which are ſet down and deſcribed in M. *Ludwig's Definitiones generum plantarum.*

§. 544. The impregnation of the ſeed happens by means of the flower-duſt or *farina*. M. *Linnæus* found the ſavin tree fruitful in the *Upſal* garden, where the male plant ſtood by; and unfruitful in the *Clifford* garden, where the male was wanting. How the *Africans* in the country of *Sherid* make the palm trees fruitful, M. *Ludwig* in his travels thither learned from the inhabitants themſelves, as he mentions in his diſputation above quoted, §. 33. The *Sheriders* are perfectly well acquainted with the difference

rence of the palm tree, whofe flowers exhibit bare duft-filaments, and the other, that only bears fruit. The palm trees of the laft fort they rear in great numbers; but thofe of the firft they keep only here and there. They ftick a branch of the duft-bearing tree near the fruit-bearing one. And thus, as they ufually fpeak, the female plant is fructified by the male. The duft or *farina* is ftrewed about by the wind, that even the palm trees ftanding in a ring are thereby fructified. In the garden of the royal academy of fciences at *Berlin* there is a female palm tree, which may be about a hundred years old, of which in the fecond part of the *Phyfical Amufements* the following particulars are related: For the laft thirty years it blowed annually, alfo bore dates, but which remained always fmall and never ripened. M. *Gleditfch* and the gardener M. *Michelman* caufed in the *April* of 1749 flowers to be fetched from *Lipfick* to *Berlin* out of the great *Bofian* garden, where ftand two male palm trees. One flower fucceeded well. But the firft and largeft bunch with the female flowers on the *Berlin* palm tree had done blowing. And thus the bunch with the male flowers was hung over thofe female flower-bunches, that were ftill the largeft. In *June* it was obferved, that the dates were grown ftouter and fuller, than otherwife they were ever wont to be about this time of year. In harveft, as they began to dry, they became ftill riper, till at length, at the beginning of the year 1750, they came to their full

ripenefs,

ripeneſs. On the bunch, over which the male flowers had hung, there were a hundred and ſome odd, but on the next to theſe, which were to one ſide and ſomewhat covered, there were only four ripe dates. On the other bunches all the dates, as in the foregoing years, remained unripe. From the ripe dates M. *Michelman* ſtuck fourteen kernels on *April* 6, 1750, in garden pots, which he had conſtantly under glaſs windows. On *Auguſt* 26, one kernel was obſerved to have ſhot. This little palm tree, which ſo early reſembled a dry, pointed ſmall graſs, gained in four months time the height of half a foot. By little and little there ſhot up ten kernels more. In 1750 the experiment was repeated with a bunch of male flowers, which were alſo fetched from *Lipſick*, and which ſucceeded well a ſecond time. In the place quoted two experiments more with other trees are related. The maſtix tree had blowed for many years in the garden of the royal academy, but never bore ripe fruit. In 1747 M. *Michelman* hung a branch of the male plant in blow over the female plant in blow, and had ripe fruit on the branch over which the male flowers had hung; from the ſeed of which he alſo reared a young maſtix tree. On all the other branches there was no ripe fruit. In the very ſame year he ſet the male and female turpentine trees in blow by each other; a thing he had never done before, tho' they had for ſeveral years already blowed. And thereby he procured ripe fruit, which before he had

never

never done, and from the ſeed thereof he raiſed young turpentine trees. Alſo the hermaphrodite plants remain unfruitful, when ſtript of the duſt apices. This Mr. *Bradley*'s experiments ſhew, which Mr. profeſſor *Kaſtner* relates in the above cited place. Mr. *Bradley* had ſet twelve tulips in a ſeparate part of the garden, where no other tulips had ſtood; and taken away their apices, as ſoon as they had blowed. And not one of them that year yielded either fruit or ſeed; though not one of 400, that had ſtood elſewhere in a bed of the garden, had failed in either. And he even certifies, that on taking away the male flowers from gourds, they gave no fruit. And that the catkins of walnuts, haſel nuts, &c. being took off, their young fruit dropt off ſo ſoon as they appeared. That the flower-duſt of the male plant may unite with the *ovarium* of the female, is what the diſcoveries, made by Mr. *Needham* chiefly in the common lilly by the magnifying glaſs, ſhews. Above, round the little pillar or piſtil, he obſerved different rows of nipples or tubercles, in ſize fitted to the little grain of the ſeed-duſt. Theſe tubercles lengthen out into tubules, that conſtitute the ſubſtance of the piſtil, and which may be ſeen with the naked eye in the marſhmallow, where the *ſtamina* ſit upon the piſtil. On cutting the piſtil acroſs, it is ſeen all over perforated with innumerable apertures. They terminate in the pithy ſubſtance of the *ovarium*, where, by little elongations, they hang together

 with

with each little grain of ſeed. This may in like manner be obſerved very diſtinctly in the marſh-mallow. Mr. *Needham* found, that theſe tubercles take into their cavities the little grains of the ſeed; with which view he ſeparated with a lancet one tubercle from the others, after the repoſitories of the ſeed-duſt, or *antheræ*, were approached to the head of the little pillar or piſtil.

§. 545. The only queſtion here is, what the duſt of the male flower may contribute to the fructifying the *ovarium?* So far as the young ſhoot or bud is contained in the ſeed before the time of blowing, we have reaſon to maintain, that only the ſubtleſt part, and as it were the exhalation, of the male flower-duſt inſinuates into the *ovarium*, and there communicates to the little ſeed-plants a certain force of expanſion. M. *Mylius* relates in the ſecond volume of the *Phyſical Amuſements*, that he found in an unripe or unfructified date-kernel no internal pith at all; but a ſhoot he found, but brown, diminutive, ſhrivelled, ſpoiled, and quite unfit for ſhooting.

§. 546. But if the form of the fruit is contained in the eggs of plants and of animals, it remains to enquire, whence theſe forms may have taken their origin? Are we to ſuppoſe in each ſpecies of plants and animals the firſt female to have contained all the forms of its ſpecies of male and of female ſex? M. *Buffon*'s objections againſt this notion (§. 535.) remain unanſwerable.

ſwerable *. Are we to imagine the little forms of all plants and animals to have ariſen at one and the ſame time by creation? If we conſider the prodigious number, in which each ſpecies of animals and plants may be propagated by generation; it remains to reflect, whether the matter of the earth, and of its water and of its air would all together be ſufficient to form at one time all the forms? M. *Buffon* in the ſecond volume of the firſt part of his *General hiſtory of nature*, chap. 2. ſhews, that did the grain of ſeed of an elm tree fully exert its generative force or quality, in 150 years there would be ſo many elm trees, that the contents of their whole matter would equal the maſs of the whole earth. Shall we ſay, that God had furniſhed matter with ſuch forces, that the individual parts by certain actions upon and againſt each other unite together according to certain regulations, and thereby form bodies with correſponding members? M. *Buffon* appeals, in eſtabliſhing his ſyſtem, to the wide-ſwaying laws of gravity and attraction. And it is not to be denied, that were the earth fully reſolved, and the parts diffuſed thro' a wide ſpace, and then left again to themſelves, but that they would by the force of gravity, whereby

* We can, indeed, by no images, which our mind can deviſe and form to itſelf, conceive of this matter, and reach to its full extent: but yet it would be acting inconſiderately, for this reaſon to reject the whole, as falſe and groundleſs. The underſtanding, not the imagination, is the meaſure of truth. *Kruger*, *Phil. Nat.* §. 669.

 they

they all together tend to a common centre, gradually unite again with each other into a mafs; in which, according to hydroftatical rules, the heavieft matter would come neareft the centre. But what is it we know of the forces, whereby organical bodies are to be formed? The force of gravity indeed impels the parts towards each other, and brings them to an equilibrium. But to the conftruction of a plant and of an animal this force of gravity is infufficient. So veiled then to our underftandings are the origins of animated bodies, that derive from generation!

PART

PART II.

Of the Sun.

CHAP. I.

Of the Body of the Sun.

§. 547. THE sun is a spherical and fiery body, whose surface consists of a fluid matter, whose parts are subtle in the highest degree, and by a vehement and constantly tremulous motion so act on the æther, that the earth receives more light therefrom, than from any other star. The spherical form of the sun may be thence known; that the sun constantly presents itself to the eye as an orb or disk (§. 482). The nature of the surface has already been discussed in treating on light (§. 213. seq.). But thence it is evident, that we are to deem the sun a fiery body (§. 215).

§. 548. But the sun consists not throughout of pure molten, and equally intense fiery matter. For, often we observe therein dark places or spots, such as were first observed by *John Fabricius* and the jesuit *Christopher Scheiner* in 1611. We are not to take these spots for any constant heavenly body, or star; for, their magnitude, figure, and density

are ever changing. Alſo in regard to the ſun's diſk they have no parallax (§. 485); ſo that we may ſafely conclude, that they come forth from the ſun's body.

§. 549. The ſpots of the ſun are neither vapours, nor matters, ſeparated from the ſurface of the ſun, and floating in his atmoſphere; neither bodies, that float on the ſurface of the ſun as in a molten ſea; but bodies, that for a while maintain their ground, and thereby become viſible in the ſun's diſk, as being neither glowing nor molten. For, ſpots, that remain viſible for a while, ſeem to move towards the limb of the ſun, each in its motion deſcribing a regular line, whoſe direction is towards a determinate point of the ſun. If a number of them appear, they retain one and the ſame diſtance from each other, as long as they laſt and continue their motion. Such things are by no means characters of a floating body, or waving vapour. Mr. profeſſor *Hauſen* in his *Theoria motus ſolis circa proprium axem*, propoſ. 14. holds the ſun for a fixt body, with many cavities in it, and covered with an entire fiery rind or ſhell. By the fire in this glowing ſhell, and in the internal parts of the fixed and perforated nucleus the matters are ſeparated aſunder, and by the elaſtick force, contained therein, forced upwards to the ſun's ſurface. If theſe ejected loads or maſſes are not fully melted, or become glowing, and project over the glowing ſurface; they appear as ſpots on the ſun's diſk. So that we are to conſider them as mountains,

mountains, arising out of the sun, and either in some time after sinking down and falling back again, when their foundations are consumed by the ever raging fire; or in time so heated by the fire of the sun's shell, as like the other parts thereof to become shining. Besides these spots, sometimes also certain dark parts, resembling a mist and fume, appear. Also many times certain places are found, which are called *faculæ*, as their light differs from the remaining lustre of the sun. These *faculæ* denote a certain pitch of glow. And what are called mists or *nebulæ* in the sun, may actually be subtly resolved matters, but which neither fully shine, and yet also ascend as pillars, and disappear.

§. 550. Though at many times in the sun there have appeared either many or large spots, yet no diminution of his heat has been observed. In the memoires of the royal academy of sciences at *Paris* for the year 1719, it is mentioned, that in the said year a spot was seen in the sun, whose diameter was to that of the earth, as 5 to 3, and consequently was four times bigger than the earth; and that in 1714 one was seen, that might be 125 times bigger than the earth. And that the cluster of spots, first observed *December* 7, 1706, would be 1728 times bigger than the earth, so it had a spherical form. How to find the height of a mountain of the sun, may be learned from professor *Kraft*'s dissertation, *De invenienda distantia macularum solarium a sole*, published in the *Comment. Petropolit.* T. 7. p. 279.

CHAP. II.

Of the Motion of the SUN.

§. 551. THE ſun in twenty-five days, fifteen hours and ſixteen minutes moves from eaſt to weſt about his axis. For, the motion, obſervable in the ſpots of the ſun, happens always towards the weſtern limb or edge of the ſun, in a regular line, directed to a determinate point in the ſun: which could not happen, had the ſun no circular motion, which that of the ſpots muſt follow. And thus the weſtern and eaſtern limbs of the ſun are every moment ſhifting. But ſo this ſhifting were imperceivable, we ſhould have taken the limb of the ſun, appearing to us to the weſt, for his weſtern limb; and that appearing to the eaſt, for his eaſtern limb. And ſo we underſtand, in what manner it may be ſaid, that a ſpot moves from the eaſtern to the weſtern limb of the ſun. Properly it is a part of the ſun, which to the eye, viewing the ſun's diſk from eaſt to weſt, is ever gaining a different ſituation to the weſt, ſo the ſun turns round his axis. That this motion is the cauſe of the motion of the ſun's ſpots, appears, beſides, from this, that their motion is quicker, when happening along the diameter of the ſun's diſk, than when paſſing along a chord. For, a point in a great circle of a ſphere, which is in motion, has a greater degree of velocity

velocity than a point in a circle, running parallel with the great circle. Several ſpots, that have diſappeared on the weſtern limb of the ſun, have in ſome days after re-appeared on the eaſtern limb. And from this the rotation of the ſun about his axis is fully evident. Of the going off, and return of the ſpots in the ſun, that appearing in the *May* of 1703 is a plain inſtance. The deſcription and draught thereof are to be ſeen in the memoires of the academy of ſciences for that year. In what manner to diſtinguiſh, that a ſpot, we had before ſeen, is the very ſame, we find in the memoires for the year 1707. After many, and carefully repeated obſervations, it has been found, that from the time a ſpot is obſerved in a certain part of the ſun, till it is ſeen a ſecond time in the very ſame part, there paſſes a ſpace of twenty-five days, fifteen hours and ſixteen minutes.

CHAP. III.

Of the Atmoſphere of the SUN.

§. 552. THE ſun is encompaſſed about with a fluid matter, different from the æther, and called his atmoſphere. In general, we underſtand by the atmoſphere of a body, a fluid matter, which exceeds it in ſubtlety, has a connection therewith, and environs its whole ſurface. The ſun's atmoſphere may be known from the following appearances. Before ſun-riſing, and after ſetting, there appears

appears at the place of rifing and fetting in a clear fky a light, having at the horizon now a larger, again a fmaller breadth, and now at a greater, and again at a lefs diftance from the fun, running pointed or tapering, and in brightnefs becoming equal to the light of the milky way. The leaft breadth was never obferved under nine or eight degrees; and the greateft, never above 20. Its leaft diftance from the fun has been obferved to be between 60 and 50; and its greateft, between 100 and 103 degrees. This light is called the *zodiacal light*. As the fun now appears to remove from our vertex more foutherly, but again to come nearer our vertex, and afcend more northerly; fo alfo this light is at the fame time with the fun obferved now more foutherly, again more northerly. From this circumftance, and from its refemblance with the light of the milky way, it appears, that the zodiacal light is withoutfide the earth's atmofphere, and appertains to the fun, or has a connection with him. The æther it cannot be. For, it throws back or reflects into our eye the light, fhooting up from the fun, under the horizon. But this is never done by the æther, whether in the night we view the ftarry heavens above, or near the zodiacal light.

§. 553. The zodiacal light differs from the morning and evening twilights; the twilights not running pointed in the manner of the zodiacal light, and having a greater breadth at the horizon.

PART

PART III.

Of the other heavenly Bodies.

SECT. I.

Of the fixt Stars.

CHAP. I.

Of the Eclipticк.

§. 554. THOSE ſtars are called fixt, that ever retain one and the ſame diſtance with reſpect to each other: aſtronomers have ranged them into certain orders or ſyſtems, by aſſuming a certain number of them together, to which they give a name. Such an order or number is called a *conſtellation*, or *aſteriſm*.

§. 555. In the night, the earth's atmoſphere being clear, the fixt ſtars appear all, as it were, equidiſtant from us, and faſtened, like ſo many ſhining points, in the ſurface of the concave ſphere of the heavens. The point to the left, on turning the face to the eaſt, is called the north; and that to the right, the ſouth. To the north is a conſtellation in the heavens, called

called the little bear. The centre of the circle, which the outmoſt ſtar in her tail appears to deſcribe, is called the *north pole*, and the ſtar itſelf the *polar ſtar*: on the contrary, the point to the ſouth, diſtant by a ſemicircle, or 180 degrees from the north pole, the *ſouth pole*. The right line, which we may imagine to be drawn from one pole to the other, is called the *axis of the world*. Beſides both the poles, there are two points more, obſervable on the immoveable ſurface of the ſphere of the world, one of which ſtands over one's vertex; and the other, under one's feet, and 180 degrees diſtant from the former. The former is called the *zenith*; the latter, the *nadir*. Through both poles, and the zenith and nadir, a circle ſuppoſed to be deſcribed on the immoveable ſurface of the ſphere of the world, is called the *meridian*. There is further a circle imagined to be deſcribed on the ſurface of the ſphere, diſtant from each pole 90 degrees, and called the *equator*, and dividing the ſphere into two hemiſpheres, the northern and the ſouthern. In the northern is the north pole; in the ſouthern, the ſouth pole.

§. 556. The ſun appears now to aſcend to a certain point from the equator northwards, again to turn back from it to the equator, and deſcend again ſouthwards to a certain point, and from that to return again to the equator. This path, which he ſeems to deſcribe, in coming in his courſe from one point to another, is called the *ecliptick*; in which

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are 12 conſtellations, or ſigns, *Aries* ♈, *Taurus* ♉, *Gemini* ♊, *Cancer* ♋, *Leo* ♌, *Virgo* ♍, *Libra* ♎, *Scorpio* ♏, *Sagittarius* ♐, *Capricorn* ♑, *Aquarius* ♒, *Piſces* ♓. The ſun appears to perform his courſe in this path from weſt to eaſt. For on viewing, for inſtance, *Aries* after ſun-ſet at the place of ſun-ſet, and after four weeks obſerving the place of ſun-ſet directly upon it; *Taurus*, which four weeks before, ſtood more eaſterly, appears, near the ſet ſun. After four weeks more, *Gemini*, which eight weeks before ſtood more eaſterly ſtill than *Taurus*, appears after ſun-ſet to be near him. In this manner the ſun appears ever continuing to move on to the following conſtellations, till he comes again to ſtand near *Aries*. The time, in which he performs this apparent motion, amounts to 365 days, 5 hours and 49 minutes, and is called the *ſolar year*.

§. 557. If we obſerve both the points, in which the ſun removes furtheſt from the equator, now to the north, again to the ſouth; the ecliptick comes to be conſidered as a circle, paſſing through both theſe points, and interſecting the equator in two other points, diſtant 180 degrees aſunder. And this circle thus divides the equator into two equal parts. The equator is a great circle of the ſphere, as dividing it into two hemiſpheres (§. 555). And conſequently too the ecliptick is a great circle; in regard every circle is equal to the circle, which it divides into two equal parts. Now as the point, from which all points in the periphery of a circle on the ſphere's ſurface

surface stand equidistant, is called its pole; so also the ecliptick has its poles, but different and distant from the poles of the world.

CHAP. II.

Of the State of the fixt Stars.

§. 558. An arch of a circle, which is described through a star and the pole of the world, intercepted between the star and the equator, is called the *star's declination*. But of a circle described through the centre of a star and through the pole of the ecliptick, the arch, intercepted between the star and the ecliptick, is called the *latitude of the star*. As there are 12 constellations in the ecliptick, in regard to these it is divided into 12 parts. But considered as a circle, into 360 degrees, each part having 30 of these degrees. The point, in which the equator is intersected by the ecliptick, as the sun appears to enter into it from the south, has the sign of *Aries*. The arch of the ecliptick, which goes from the beginning of this sign to the point, in which the circle of latitude of a star intersects the ecliptick, is called the *longitude of the star*. By the latitude and longitude of a star, its place is determined. Or, knowing its longitude and latitude, we also know its place. And by the longitude and latitude found, the fixed stars are disposed on the celestial globe.

§. 559.

§. 559. From comparing the obſervations, made for ages back to our time, it appears that the longitude decreaſes in all the fixt ſtars in an equal quantity. This decreaſe amounts yearly to 50 ſeconds, and conſequently in 72 years to a degree. And knowing the longitude of a ſtar for any particular year, we may find it in any other year, either preceding or following the year in which it was known. And follow the year, in which we would know the longitude, that in which it is known; you add to the known longitude ſo many 50 ſeconds, as there are intermediate years. For inſtance, by *de la Hire*'s tables, the longitude of the dog-ſtar at the beginning of the year 1701 was $9^{\circ}\ 57'\ 33''$ in *Cancer*. And adding thereto 52 times 50, that is 2600 ſeconds, the longitude for the year 1753 = $10^{\circ}\ 40'\ 53''$. In the latitude no alteration has hitherto been obſerved. And therefore the fixt ſtars appear to move from weſt to eaſt in circles, parallel to the ecliptick. The entire apparent revolution happens in 25920 years; as being the number ariſing, on multiplying 360 degrees by 72 years, the time in which a ſtar appears to move about a degree. And ſo, ſome centuries before our Saviour's birth, the firſt ſtar of *Aries*, into which conſtellation the ſun, after his apparent return from the ſouth, appears to come, had its place at the interſection of the equator and the ecliptick, whereas now it is removed from it about 30 degrees to the eaſt. But though the 12 conſtellations in the ecliptick, do all of

of them move out of their places; yet the places, in which they formerly ſtood, are ſtill denominated from them, and marked with their ſigns. When the ſun in his apparent motion from the ſouth enters the interſection of the equator and ecliptick, he makes the vernal equinox. And entering it, before the birth of Chriſt, at the time, when the firſt ſtar of *Aries* was in the ſaid interſection, he made the vernal equinox on coming to the firſt ſtar of *Aries*. In 72 years after, he made the equinox, before he came to the firſt ſtar, as being now a degree diſtant from it. And this we call the *anticipation* or *preceſſion of the equinoxes*.

§. 560. On comparing the obſervations of the ancient aſtronomers with thoſe of the modern, we find alſo that the declination of the fixt ſtars changes. In the year 1697 the diſtance of the polar ſtar from the pole was 2° 18′ 50″, and therefore the declination of this ſtar was 87° 41′ 10″. Whereas in the days of *Eudoxus* the pole-ſtar was 12° diſtant from the pole: ſo that then the declination of the pole-ſtar was 78°.

From the variations of the longitude and declination of the fixt ſtars it is thus evident, that a celeſtial globe, in ſome time after it is made, does not duely ſhew their true poſitions. M. *Caſſini* exhibited a globe to the academy of ſciences, whoſe uſe is conſtant, without requiring any alteration, either to be actually made, or to be ſuppoſed. Mention is made thereof in the memoires for the year

1708. It turns as well round the axis of the equator, as all other globes do, as about the axis of the ecliptick, which is the peculiarity in this globe. A circle is deſcribed about the pole of the ecliptick, whoſe radius is 23° ½. This circle the pole of the equator is to revolve in, in 25920 years. Now on reducing, for a certain epocha, the pole of the equator to its proper point in this circle, there you fix it down. And thus the globe revolves not barely about the axis of the equator, as is neceſſary for the uſual operations. And you may inſtantly ſee, what poſition of the heavens obtained in the days of our anceſtors, as alſo what will obtain in thoſe of our poſterity.

SECT. II.

Of the PLANETS.

CHAP. I.

Of the Diſtinction of the PLANETS.

§. 561. THE *planets*, or ſtars, which change their diſtance as well among themſelves, as alſo are now ſeen at this, again at that fixt ſtar, are partly *primary*, partly *ſecondary*. The *primary planets*

revolve round the Sun ☉, as *Mercury* ☿, *Venus* ♀, *Mars* ♂, *Jupiter* ♃, *Saturn* ♄. The *secondary planets*, or *moons*, or *satellites*, revolve round a planet. A body revolves about another, when that other is considered as the point, by which the revolving body constantly regulates itself in its path or course. Round the earth a single satellite only, called simply the moon ☽, revolves: whereas round *Jupiter* there revolve four, and round *Saturn* five satellites or moons. *Simon Marius*, mathematician to the margrave of *Brandenburg*, towards the end of *November* 1609, first discovered three of *Jupiter*'s satellites, and also the fourth in the *January* and *February* of the following year. *Galileo* observed them in *Italy* on the 7th of *January* 1610, and the same year described them in his *Nuncius Sidereus*. *Huygens*, *March* 25, 1655, first discovered a satellite about *Saturn*. But *Cassini* afterwards discovered four more.

CHAP. II.

Of the Light of the PLANETS.

§. 562. THE light, whereby the planets are discernible, arises not solely from their proper force or virtue. The moon appears sometimes only as a fully luminous disk; this state is called *full moon*. Soon after, the disk comes to exhibit still less and less light, till at length there is none at all perceivable; this last state is called *new*

moon.

moon. The middle ſtate between both theſe, when the half diſk ſhines, is called *quarter moon*, and divided into firſt and laſt quarters. The firſt ariſes after new moon, when the half diſk ſhines weſtward; and the laſt, after full moon, when the half diſk ſhines eaſtward. Alſo ☿, ♀ and ♂ appear not at all times with diſks fully luminous, when viewed through teleſcopes. It may be plainly perceived, that the light of their ſurfaces, obverted to us, now decreaſes, again increaſes. In *England*, *Horrox*, *November* 24, 1639, firſt obſerved *Venus* in or under the ſun as a dark body. This phænomenon we are again to expect not before *May* 25, 1761. *Mercury* has been ſeveral times obſerved to paſs under the ſun in form of a black and dark ſpot. The firſt obſervation was made by *Gaſſendi*, *November* 7, 1631. If *Jupiter* comes into ſuch a ſituation between his ſatellites and the ſun, as that a right line may be drawn through them, him and the ſun, his ſatellites become inviſible for a while. The very ſame thing befals the ſatellites of *Saturn*, on his having a like poſition between them and the ſun. Had *Saturn* and *Jupiter* and their ſatellites on the ſurfaces, which they obvert to each other, a proper light; neither thoſe would project a ſhadow on theſe, nor theſe become inviſible therein. Had the light, we obſerve in the moon, its origin from no other ſtar, but herſelf, the ſurface, which ſhe conſtantly turns to us, would never loſe its light. The very ſame thing is to be affirmed of the light, that appears on

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the ſurfaces of *Mercury*, *Venus*, and *Mars*, obverted to us; as partly gradually decreaſing, partly diſappearing quite on the ſurfaces, that *Mercury* and *Venus* obvert to us, at the time, both theſe planets ſtand under the ſun.

§. 563. The light, the planets exhibit, is excited by the rays of the ſun. When the moon, after ſun-ſet, is ſeen near the weſtern horizon; we only obſerve a ſtripe or ſtreak illuminated on her ſurface. But the farther ſhe removes from the ſun, a larger part becomes viſible to us. If ſhe ſtands at length, in reſpect to our earth, directly oppoſite to the ſun, and thus diſtant by half the heavens from him; ſhe is full. Now if ſhe proceeds farther, the light of the diſk is ever diminiſhing, the nearer ſhe approaches to the ſun. At length the diſk loſes its light quite, when ſhe and the ſun may be ſeen in one and the ſame part of the heavens. But that very ſurface, which ſhines with full light, when in oppoſition with the ſun, comes to fail of light, when turned away from him, as between it and the ſun is interpoſed the body of the moon. And thus the light of this ſurface is cauſed by the ſun's rays. In like manner, that part only which their ſurfaces obvert to the ſun, is enlightened in *Mercury*, *Venus* and *Mars*. And thus in the ſatellites of *Jupiter* and *Saturn* that ſurface becomes darkened, that cannot be irradiated by the ſun, when *Jupiter* and *Saturn* with-hold his rays. Alſo the ſurface, which *Jupiter* obverts to the ſun, has its light from the ſun. For, if the ſatellites

tellites of *Jupiter* ſtand between him and the ſun, we come to obſerve on *Jupiter*'s ſurface ſmall round ſpots, which advance progreſſively on the ſurface, as the ſatellites ſhift their places. *Saturn* is encompaſſed about with a ring, but without being faſtened to his ſurface. At certain times we may ſee thro' between *Saturn* and his ring, and diſcern the fixt ſtars. The breadth of the ring is as large as is the diſtance of its inner rim from the ſurface of *Saturn*. This ring at ſome times projects a ſhadow on the ſurface, that *Saturn* oppoſes to the ſun. From this it appears, that the ring is not only an opake body, but alſo that the ſurface of *Saturn*, obverted to, has its light from the ſun. The ring itſelf is enlightened only, when the ſun's rays reach it. And thus neither its inner, nor its outer rim ſhines by its own peculiar force or virtue. In what manner and under what forms *Saturn*'s ring exhibits itſelf to the eye, Mr. profeſſor *Heinſius* has explained in his *Commentatio de apparentiis annuli Saturni*, publiſhed at *Lipſick* in 1745.

§. 564. But though the light of the planets is produced by the ſun's rays, yet it conſiſts not in reflected ſolar rays; for otherwiſe, we ſhould have ſeen the ſun on the ſurfaces of the planets (§. 290.) The ſun's rays put the particles of the planetary ſurfaces into a tremor or vibration, which excites pulſes in the æther, from whoſe propagation the rays of light ariſe (§. 291.)

CHAP. III.

Of the ECLIPSES.

§. 565. A HEAVENLY body is eclipſed, when deprived of light; if between it and thoſe bodies, by whoſe force it ſhines, a dark and opake body interpoſes; ſo *Jupiter* and *Saturn* eclipſe their ſatellites.

§. 566. If the moon comes between the ſun and the earth, the parts of the earth's ſurface, on which a right line may be drawn through the moon and ſun, are deprived of the ſun's light. This covering of the ſun by the moon is uſually called a *ſolar eclipſe*, as the ſun appears to loſe his light. But properly it is an *eclipſe of the earth*. And thus ſuch a ſolar eclipſe happens at new moon (§. 562.), and is therefore natural and common. On the day our Saviour ſuffered, the ſun loſt its light at *full moon*, the moon being 180° diſtant from him. This appearance therefore was no uſual and natural *ſolar eclipſe.*

§. 567. The ſun will be covered to a part of the earth's ſurface by the moon, either entirely, or only partially. The firſt is called a *total*; the ſecond, a *partial ſolar eclipſe.* The total ariſes in thoſe places, over which the full ſhadow of the moon paſſes: on the contrary, the partial, in thoſe places, on which the moon's penumbra comes (§, 300. 306). A partial ſolar eclipſe is now greater, again leſs, according as the place, over which the penumbra paſſes,

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is now nearer to, again farther from the centre of the ſhadow. In total ſolar eclipſes we ſometimes obſerve a bright ring, which ſeems to go round the covered ſun; but ſometimes none. The repreſentation of theſe ſeveral ſpecies *Doppelmaier's Atlas cœleſtis* exhibits, chart 13. For obſerving the ſolar eclipſe, which *July* 25, 1748, proved annular in ſome places, M. *Lowiz* publiſhed beforehand at the very beginning of that year two aſtronomical charts or maps, with an explanation.

§. 568. The full moon begins to be eclipſed, when the earth is ſo poſited between her and the ſun, that a right line may be drawn from the ſun through the earth to the moon. Lunar eclipſes therefore are cauſed by the ſhadow, which the earth projects on the moon. And thus if the earth's ſhadow touches the entire diſk of the moon; the lunar eclipſe is total or compleat. But be only a part of the moon's diſk hit by the ſhadow; it is partial.

§. 569. In ſolar eclipſes the weſtern limb of the ſun is firſt covered, and alſo firſt uncovered again; but in lunar eclipſes, the ſhadow firſt touches the eaſtern limb of the moon, and alſo firſt quits it again. A lunar eclipſe is viſible at once, and of equal magnitude, in all places of the earth's ſurface, ſo the moon at the time of the eclipſe appear above the horizon of theſe places. The reaſon is, that the earth ſuffers not the ſun's rays to fall on the moon's ſurface, ſtanding oppoſite to theſe places of the earth's ſurface. But though two places, of

which one lies more weſterly, obſerve a lunar eclipſe at the ſame inſtant; yet both reckon not their hours the ſame. For inſtance, *February* 22, 1701, the lunar eclipſe happened at *Paris* about 10 h. 15′ 23″, and at *Berlin* about 10 h. 59′ 36″. This difference amounts to 44′ 13″. The reaſon for this is to be ſought for in the point of time, from which any one begins to reckon the hours. This beginning of reckoning is made, when the ſun appears in the meridian. But he comes into it at one place, which lies more eaſterly, ſooner than at another, that lies more weſterly. For inſtance, at *Berlin*, which lies more eaſterly than *Paris*, it is 44′ 13″ ſooner noon there than at *Paris*. But the time being conſidered in the general or abſtract, without regarding the number of the hours; the moon was eclipſed at the very ſame point of time, both at *Berlin*, and at *Paris*. But in this point of time they reckoned at *Berlin* 10 h. 59′ 36″, and at *Paris* 10 h. 15′ 23″. A ſolar eclipſe happens at a place, that lies more weſterly, ſooner than at another, that lies more eaſterly. For inſtance, at *Paris* in 1706, the ſun loſt his light above 44′ ſooner than at *Berlin*; and at *Madrid*, which lies more weſterly than *Paris*, almoſt 23′ ſooner than at *Paris*. The reaſon of which is, that the lunar ſhadow is not ſo big, as compleatly to cover the half ſurface of the earth, towards which the ſolar rays take their way; as baron *Wolfius* ſhews this in his *Elementa Aſtronomiæ*, §. 1035.

§. 570.

§. 570. In ſome lunar eclipſes, the moon, in a clear ſky, in which the ſmalleſt fixt ſtar is perfectly well diſtinguiſhable, has become entirely inviſible; but in ſome again, ſtill continued viſible. So *April* 14, 1642, the moon in her total eclipſe was not to be ſeen at *Bologna*, and in ſeveral places in *Holland*. On the contrary, at *Venice* and *Vienna* ſhe was perfectly well diſtinguiſhable. At *Venice* ſhe appeared quite red. The moon in the total eclipſe of *December* 23, 1703, appeared at *Arles* of a dark red and a brown; but at *Avignon* of a bright red; as to the eye, to ſeem as if the ſun ſhone through her from the other ſide. But at *Marſeilles* ſhe appeared reddiſh to the north-weſt, and quite dark to the ſouth-eaſt, and diſappeared entirely in a quite clear ſky. Baron *Wolfius*, from credible authors, relates theſe phænomena in his *German elements of aſtronomy*, §. 267. The origin of the light and colours, which are ſometimes to be obſerved in the moon, when compleatly covered by the ſhadow of the earth, is to be ſought for in the refraction, which the ſolar rays, paſſing along the earth, undergo. And thus theſe refracted rays paſs to and fro through the earth's ſhadow, and produce on the moon's ſurface a light, which is different according to the different degrees of the refraction.

CHAP.

CHAP. IV.

Of the Nature of the PLANETS.

§. 571. IN the moon and in *Venus* there are mountains. For, if only a part of their ſurfaces, obverted to us, is enlightened; without the limits of the light here and there ſome bright places appear. Theſe therefore muſt project over the other places in the unenlightened part. *Galileo* plainly obſerved the ſhadow of the lunar mountains.

§. 572. On the enlightened ſurface of the moon ſome parts are diſtinguiſhable from the others by a certain degree of darkneſs. In theſe ſpots appear here and there ſmall bright-ſhining parts. The ſpots themſelves have for a long time been taken for ſeas; and the bright parts, which appear in them, for iſlands. *Hevelius* delineated the appearance of the moon at full. *Riccioli* on the contrary, at the decreaſe and increaſe from her ſtripes or ſtreaks, and from theſe put her appearance or form together. On the lunar chart of *Hev elius* the ſeveral regions, mountains, ſeas, rivers, and iſlands have names aſſigned them from the like parts on the earth's ſurface. But *Riccioli* on his lunar chart has diſtinguiſhed the ſeveral parts of the moon's ſurface by the names of celebrated aſtronomers. Both charts are to be met with in *Doppelmaier*'s *Atlas cæleſtis*.

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The ſpots, which at firſt were taken for rivers and ſeas, are properly cavities or deep caverns, whoſe bottom naturally appears darker; as *Galileo* firſt, and after him *de la Hire*, diſcovered. In *de la Hire*'s reflections on the appearance or form of the lunar body, which are to be ſeen in the memoires of the royal academy of ſciences for the year 1706, the following important remarks are alledged. When the ſun directy enlightens the lunar mountains and cavities, they come to be ſcarce diſtinguiſhable. Many diſappear quite; and many ſhining parts come to view, which before did not. For inſtance, at full moon large bright rays are ſeen round the cavity or ſpot *Tycho*, which appear not on the mountains and ſpots, over which they proceed, when theſe parts are enlightened from one ſide, and ſtand at the rim or edge of the ſhadow. The very ſame ſpot, that appears very bright, when enlightened from before, is only a ſmall cavity with a mountain in the middle, not diſtinguiſhable from innumerable others around it. The ſmall ſpot *Ariſtarchus*, ſo bright, as by ſome to be taken for a volcano, is only a ſmall cavity, diſtinguiſhable from others around it, when it comes to ſtand at the edge of the ſhadow. It cannot be well affirmed, that all theſe bright parts are ſpecies of *phoſphori*, that kindle on being enlightened directly by the ſun; and come to be without light, when the ſun enlightens them acroſs or from one ſide. For, they have the very ſame effect in the dark, when the moon is only enlighten-
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ed by the rays, which come to her from the earth. We are rather to ſeek for the cauſe in the figure of theſe parts and in the reflection of the ſolar rays. For, the ſun meeting in theſe parts with a ſpecies of concave ſpecula, not perfectly even or poliſhed, but in ſurface very white, the eye is affected by them, as by a true light. Were theſe concave ſpecula ſmooth, we ſhould come to obſerve in them only a ſmall bright point. The cavity muſt appear quite bright, when enlightened directly by the ſun. But the ſolar rays coming from one ſide, this light muſt gradually decreaſe; and they can now no longer be reflected to the eye. To this add, that the ſhadow of the edge of the cavity falls into the cavity itſelf, and darkens it. With reſpect to the bright rays, going forth from the ſpot *Tycho*, the caſe is different. When many eminences and cavities, in a certain aſpect to the ſun, are made equally bright; mountains and cavities appear no longer ſeparated aſunder and interrupted. And hence it comes that the apparent form of the full moon differs ſo very much from her real form. And that too is the cauſe of the ſhine or light of the rays of *Tycho*. *De la Hire* ſays, that the body of the moon reſembled a demi-relievo in ſculpture, whoſe parts were plainly diſtinguiſhable, on the light falling from one ſide thereon; but whoſe figure at the ſame time was ſcarce diſtinguiſhable at a moderate diſtance, on the ſun's ſhining directly thereon. With this view, in order to be aſſured thereof by experience, *de la Hire* cauſed

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to form in relievo a ſmall part of ſome ſpot on the moon's ſurface; and in the different poſitions, in which he expoſed it to the ſun, he found, that it had almoſt the very ſame appearance with the repreſented part of the moon.

Since the time that teleſcopes have been invented, no obſervations have been diſcovered in the moon's body, like what our earth at ſome times undergoes. Did ſuch alterations happen on her ſurface, they could not fail of being obſerved. For, ſuppoſing the city of *Paris* ſtood on the middle of the lunar diſk; through a teleſcope of 25 feet focal diſtance, it would appear to us from the earth as large, as what is called the *Mare criſium*, appears on the moon's diſk to the naked eye. M. *de la Hire* proves it as follows: every body is ſeen under a certain angle (§. 193). But one and the ſame body appears under one and the ſame angle, be it viewed either in the moon from the earth, or on the earth from the moon. For, the diſtance of the body from the eye is in both caſes one and the ſame. Now *Paris* takes up on the earth a ſpace of two minutes. The ſine of 2′ is to the radius or ſemidiameter, as $58\frac{1}{10}$ is to 100000. We will aſſume it, as 60 to 100000, or as 6 to 10000, or as 3 to 5000. If we view this part 3 of the moon through a glaſs, which magnifies an object 100 times; it will appear under an angle 100 times greater. And thus if *Paris*, as ſtanding on the middle of the earth, was viewed through ſuch a teleſcope from the moon,

moon, it would in appearance be to the ſemidiameter of the earth, as 300 to 5000, or as 3 to 50. And now aſſuming the diameter of the moon half as big as the ſemidiameter of the earth, and that *Paris* was tranſlated to the middle of the moon's body; it would there have in length the proportion to the moon's diameter, that 3 has to 25. Now 3 is an eighth part of 25 nearly. And thus *Paris* would appear in length almoſt as big as the eighth part of the moon's diameter: but ſo large is the *Mare criſium*. And thus if *Paris* ſtood on the middle of the moon's diſk, it would appear from the earth through a teleſcope of 25 feet as large as the *Mare criſium* does to the naked eye.

§. 573. Round the moon is an atmoſphere, or a fluid matter, in which the incident rays of the ſun are refracted. This atmoſphere the chevalier *Louville* aſcribes to the moon, as having in *London* on *May* 3, 1715, N. S. obſerved along with Dr. *Halley*, in the total eclipſe of the ſun, a bright circle or ring about the moon. This obſervation is deſcribed in the memoires of the royal academy for the year 1715. The principal proof he adduces therein, in favour of the moon's atmoſphere, conſiſts in the following particulars. The apparent diameter of the moon at the time of the eclipſe was $= 33' \, 28''$, or $2008''$; and the apparent diameter of the ſun $= 31' \, 54''$, or $1914''$. And thus the apparent diameter of the moon exceeded that of the ſun about $94''$. Now allowing the moon's diſk 12

equal

equal parts, called *digits*, ſuch a digit contained at that time 167″. And thus the apparent diameter of the moon exceeded the apparent diameter of the ſun at the very ſame time about ſomething more than half a digit. The breadth of the ring amounted to a digit of the moon's diſk. At the beginning of the total eclipſe, or entire veiling of the ſun, the weſtern limb of the moon projected more than half a digit beyond the weſtern limb of the ſun; ſo that the bright circle ſhould have been covered by the moon's limb on the weſt ſide above half. But it was not covered at all. At the end of the total eclipſe the ring or circle on the eaſt ſide ſhould in like manner have been covered above half. But here too the contrary was obſerved. The chevalier *Louville* writes, that he rather obſerved, that the ring at the beginning, middle and end of the eclipſe, was exactly concentrick with the moon; and hence concludes, that this circle followed the motion of the moon and not of the ſun. And thus the ring is produced by the atmoſphere of the moon refracting the rays of light incident on it, and thereby conveying them to the ſpectator's eye on the earth. It is true it was not every where equally bright. But the interruption of this light *Louville* aſcribes to the mountains of the moon intercepting the following rays.

Mr. profeſſor *Euler*, by the obſervations he made *July* 25, 1748, at *Berlin*, on the annular eclipſe of the ſun, has in the *Memoires de l'academie royale des ſciences et belles lettres* for the ye 748, p. 103. ſeq.

ſeq. ſhewn anew, and in a diſtinct manner, the moon's atmoſphere. Fig. 3. plate VIII. exhibits the lunar and ſolar diſks with the ring. A Z B N is the ſun's diſk, Z N his vertical line drawn through the vertical point Z and the oppoſite point N, and A B his horizontal line, whoſe extremity A denotes eaſt; and B, weſt: *a z b n* is the moon's diſk. The right line E F, paſſing through the points C and *c*, as the centres of the ſun and moon, appeared to be diſtant from the vertical line Z N under an angle of about 40°. The greateſt breadth of the ring was F *f*; the leaſt, E *e*, and equal to the fourth part of the greateſt F *f* nearly. The apparent ſemidiameter of the ſun was at that time = 952″, and the apparent ſemidiameter of the moon = 898′. The leaſt diſtance of the ſun's centre C from the moon's centre *c* amounted to about 53′. We will preſuppoſe, that the ſun's diſk underwent no apparent amplification in the part F *f*, where the ring was broadeſt. And beſides, theſe amplifications were only obſerved in the places, where the limbs of the ſun and moon came neareſt in contact to each other. So that C F = 952′, *c f* = 898″, and C *c* = 53″, and conſequently C *f* = 845, and therefore the greateſt breadth F *f* of the ring was = 107″. Now had the ſun's diſk, with reſpect to the leaſt breadth of the ring in the part E *e*, undergone no apparent amplification; the leaſt breadth E *e* had been 1′. For, C E, the apparent ſemidiameter of the ſun's diſk, is = C F, and conſequently = 952″, and *c e*, the apparent ſemidiameter

ſemidiameter of the moon's diſk, is $= cf$, and conſequently $= 898''$. Now C c is $= 53''$. And thus if ce and C c are added together, C e is $= 951''$. And if C e, $= 951''$, be ſubtracted from C E $= 952''$, there remains $1''$. This therefore ſhould be the leaſt breadth of the ring in the part E e. But it appeared as large as the fourth of the greateſt breadth F f; and was therefore $= 26''$, the fourth of 107. Now if from the number 26 you deduct a ſecond, E e is $= 25''$. And thus the ſun's diſk, in the places where his limb and that of the moon had touched each other the cloſeſt, appeared larger and more amplified. If from the outmoſt limb of the ſun A fig. 4. plate VIII. the ray A T raked along the point M of the moon: in that caſe the ſpectator on the earth at T, to whoſe eye the ray came from A, ſhould have ſeen the limb A along the line T A, and conſequently at the limb of the moon. But the ſpectator ſaw the ſun's limb along the line T a, and conſequently the point A in a. The angle A T a amounted to $25''$. And thus by ſo much was the apparent place a diſtant from the true place A of the ſun's limb. Now whence has this difference ariſen? and why appeared the outmoſt limb of the ſun, not in A but in a? It might be ſurmiſed, that at the time the moon ſtood under the ſun, her diameter appeared leſs than it would, if viewed in another place. But M. *Euler* intimates, that all the time of the eclipſe, the moon's diameter was meaſured, and no apparent diminution obſerved. The cauſe of

of the apparent amplification of the ſun's diſk, or of the bright ring round the ſun or moon, is therefore to be ſought for in a refraction, which the ſun's rays underwent at the ſurface of the moon. And thus a fluid matter, denſer than the æther (§. 164.) muſt needs encompaſs the moon, out of which the rays of the ſun paſs to the moon.

As the breadth of the ſun's ring was enlarged or amplified about 25″ only by the refraction of the moon's atmoſphere; the air of the moon muſt be uncommonly rare. Mr. profeſſor *Euler* rates it at 200 times rarer than the air of our earth. For, if a ſtar appears at the horizon, it ſeems to be elevated above it by the refraction upwards of half a degree (§. 188). If therefore the lunar atmoſphere was ſo denſe, as the terreſtrial, a ſtar at the moon's limb would appear diſtant from her above a whole degree. For, a ray, paſſing from a ſtar along the earth's horizon to the eye, is refracted only once, as it goes barely out of the æther, as a rarer matter, into the air of the earth, as a denſer ſubſtance, and in this very air of the earth comes to the eye. But a ray, paſſing from a ſtar along the moon's limb, and to the earth to the eye of a ſpectator, is refracted twice, before it comes into the earth's atmoſphere: once, on going out of the æther, as a rarer matter, into the lunar air; and a ſecond time, on paſſing again out of the lunar air, as a denſer matter, into the æther towards the earth (§. 164). So that the point *a* fig. 4. plate VIII. to which the image of a ſtar is

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by the refraction of the lunar air conveyed, ſhould be above a degree diſtant from the true place A, where the ſtar really is. But this diſtance in the ſun's annular eclipſe of *July* 25, 1748, was only 25″. M. *Euler* in general ſets ſuch an apparent diſtance only at 20″. But 20″ are to a degree, or 3600″, as 1 to 180. And thus this extreme rarity may be the reaſon, why no obſervable vapours ariſe therein. But poſſibly too the matter of the moon is ſo firm and dry, as to be incapable of evaporating.

The younger M. *de l'Iſle* would derive the bright circle, which *Louville* obſerved *May* 3, 1715, in the ſolar eclipſe, not from the refraction, but from the inflection of the ſolar rays (§. 184). He cut a circle out of a plate of lead, and held it directly oppoſite to a bright cone of the ſun, which he tranſmitted through a ſmall hole into a perfectly dark room, ſo as to cover the entire image of the ſun, and ſtand diſtant before it. Then he viewed this artificial ſolar eclipſe on a white paper behind the round plate, and very diſtinctly ſaw the ſhadow of the circle on the paper, but encompaſſed round with a well-defined bright ring, ſuch as *Louville* had ſeen round the ſun. But this appearance in no manner claſhes with a lunar atmoſphere. What is called an inflection is properly a refraction. Round the lead orb or circle there is not barely air, ſuch as is found before and behind it; but alſo electrical matter (§. 241, 242), which, together with the air round the lead circle, conſtitutes a fluid ſubſtance, that is denſer than the

air before and behind this circle. And if the terrestrial air is every where mixed up with electrical matter, it is far denser at the surface of the metal, than in the bare air.

§. 574. In *Venus*, *Mars*, and *Jupiter* there often appear different spots, on viewing these planets through a telescope Under the appellation, *spots*, are understood all the parts of the visible disk of a planet, that distinguish themselves from the other parts, either by a greater degree of darkness, or by a greater degree of brightness. So M. *Maraldi*, in 1719, observed a bright spot in the south pole of *Mars*. Formerly too such a bright spot was seen at the north pole of *Mars*. The remarks thereon are contained in the *Memoires of the academy of* Paris. In *Mars* and *Jupiter* there are spots, that extend like stripes or *fasciæ* over the disks of these planets. M. *Cassini*, in 1699, observed in the centre of *Mars* on a slender stripe or belt a dark spot, whose length was equal to a sixth of *Jupiter*'s semidiameter, and breadth, to its half length; at the same time he besides observed more spots and stripes. His observation is exhibited in the *Memoires of the academy* for the year 1699, with a description of the return of an old spot of *Jupiter*, and the observation of a large spot in his fourth satellite. In the history given, in of the above *Memoires* of 1699, of the spots, *Maraldi* had observed in *Mars*, it is concluded from their alterations, that great changes happen on this planet. And in the history,

hiſtory, which precedes *Caſſini*'s obſervation of three new ſpots in *Jupiter*, the alterations of his ſpots and belts, which now turn broad, again narrow; again ſeparate, and again come together, are deemed more important, than if the ocean overflowed the whole firm land of our ball, and laid bare, where it had ſtood before, new land *. The earth, it is at length added, muſt, in compariſon of *Jupiter*, enjoy a great degree of tranquillity, and ſtand free from natural alterations. From *March* 25 to the end of *April* 1715, *Caſſini* obſerved on *Saturn*'s diſk three dark, ſtraight, and parallel ſtripes; the middlemoſt was the ſhadow of his ring. As the other two were tranſitory, *Caſſini* held them for large clouds contained in *Saturn*'s atmoſphere. Both his, and *Maraldi*'s obſervations and reflections on theſe ſtripes or belts of *Saturn*, are contained in the *Memoires of the academy of ſciences at* Paris, for the year 1715.

CHAP. V.

Of the apparent MOTIONS of the PLANETS.

§. 575. THE moon and the primary planets, like the ſun, appear not only to move from eaſt to weſt round the earth in 24 hours, but alſo at certain times from weſt to eaſt. The former is called the *common*, and the latter the *proper motion*.

* Whether theſe alterations may not be apparent, and owing to the different poſitions of the belts to the eye?

tion. The proper motion, as in the caſe of the ſun, is hence diſcovered, that in ſome time, after he has been ſeen at certain ſtars, he is obſerved to be at other ſtars, which, at the time of obſerving him at the former, ſtood more eaſterly.

§. 576. In the proper motion the primary planets and the moon appear now to aſcend above the ecliptick more towards the north pole; again, to deſcend under the ecliptick more to the ſouth pole. The diſtance from the ecliptick north and ſouth amounts to about ten degrees. At this diſtance to north and ſouth a circle is drawn. Both circles are parallel to the equator, and called *circles of excurſion*, and include a ſpace, called the *zodiack*; which, like the ecliptick, is divided into twelve ſigns, and that by circles, that are drawn through the poles of the ecliptick, and the beginning of each ſign.

§. 577. As we repreſent to ourſelves the ecliptick on the outmoſt ſurface of the ſphere of the world, we may there alſo imagine the curve line, which the centre of a planet in its motion appears to deſcribe, or its path to be. The points of the ecliptick, in which it is interſected by this elongating or deviating path of a planet, is called the *nodes*; and the one the aſcending ☊, from which the planet aſcends above the ecliptick to the northern ſigns; and the other the deſcending ☋, from which the planet goes out of the ecliptick to the ſouthern ſigns.

§. 578. If two ſtars are ſeen in one and the ſame place of the heavens; this aſpect is called their *conjunction.* But if diſtant aſunder by the half of the

heavens,

heavens, or 180 degrees; this appearance is called their *oppoſition.*

§. 579. The moon, *Saturn*, *Jupiter*, and *Mars* remove at certain times from the ſun quite to the oppoſition; whereas *Venus* not above 47°, and *Mercury* not above 28°. The conjunction of *Venus* and *Mercury* happens at one time above; at another, under the ſun. For, in one conjunction they have no light; and then they are under the ſun (§. 562). In the other conjunction they are full; and thus in that caſe they are above the ſun.

§. 580. The moon, in order to be eclipſed by the earth, muſt be in oppoſition to the ſun, and either in the node, or ſo near it, that the moon's latitude is leſs than the ſum of her apparent ſemidiameter and the ſemidiameter of the earth's ſhadow. For, the moon is only eclipſed when at full (§. 568), and conſequently diſtant by half the heavens from the ſun (§. 563). This is called her oppoſition (§. 578). The earth's ſhadow, by which the moon is eclipſed, projects or falls oppoſite to the ſun, that is, at a place, diſtant 180° from him. But the ſun is in the ecliptick (556). And thus the earth's ſhadow falls to the place of the ecliptick, that is diſtant 180° from the ſun; ſo that the moon muſt needs be eclipſed, when her centre falls into the ſaid point. But then the moon is in the node (§. 577). For inſtance, in N, fig. 5. plate VIII. where the moon's path F O and the ecliptick R R mutually interſect. As the earth's ſhadow is a circle, one ſemidiameter

thereof extends ſouthwards; the other, northwards. Now if the centre of the moon be without the node; for inſtance, at I or G; but ſo near the node, as that her ſemidiameter may be touched by the ſemidiameter of the earth's ſhadow; ſhe will be alſo eclipſed without the node. And thus the diſtance of the moon from the eclyptick, or her latitude (§. 558), is leſs than the ſum of her apparent ſemidiameter, and of the ſemidiameter of the earth's ſhadow. For, the latitude of the moon is the diſtance of her centre from the ecliptick. Now if the ſhadow be within, and the moon without it; the latitude of the oppoſite moon is the diſtance of her centre from the centre of the earth's ſhadow, as of a circle. If the diſtance of the two centres of the two circles is greater than the ſum of both their ſemidiameters; neither can touch either; as for inſtance, F and A.

§. 581. The moon, in order to cover the ſun from the earth, muſt be in conjunction with the ſun, and be either in the node, or ſo near it, that her latitude, as it appears from the earth, is leſs than the ſum of the apparent ſemidiameters of the moon and ſun. For, the ſun can only be eclipſed or covered, when the moon ſtands between him and the earth (§. 566). But ſhe is then in conjunction (§. 577); which happens either in the node, where the moon's path interſects the ecliptick (§. 577), or near the node. If the moon is in the node, along the line, which may be drawn from the centre of the ſun

through

through the centre of the moon, no light of the ſun, on account of the moon's opacity, can reach that part of the earth's ſurface, to which the ſaid line may be drawn. If the moon is without the node; but ſo diſtant from the ecliptick, that her latitude is greater than the ſum of her apparent ſemidiameter, and of the apparent ſemidiameter of the ſun; the limb of the moon, by the propoſition, which was advanced at the cloſe of the foregoing ſection, cannot touch or cover the limb of the ſun. The moon therefore, in order, without the node, to cover the limb of the ſun, muſt have her latitude leſs than the ſum of the ſaid ſemidiameters.

§. 582. The five primary planets appear only for ſome time to move in the zodiack in the order of the ſigns from weſt to eaſt; but at other times to move retrograde to the ſigns, from which they were come; ſometimes alſo to ſtand ſtill. *Saturn*, *Jupiter*, and *Mars* againſt the time of their oppoſition to the ſun; and *Venus* and *Mercury* againſt the time of their conjunction under him, are retrograde. In the retrogradation *Jupiter* deſcribes a greater arch than *Saturn*; and *Mars*, a greater than *Jupiter*. The arch of *Mars* retrograde is nearly 12; of *Jupiter* retrograde only 10, and of *Saturn* retrograde only 7 degrees. But yet *Mars* takes only 73; but *Jupiter*, 120; and *Saturn*, 140 days to the retrogradation. The ſun and the moon appear neither to ſtand ſtill, or to be ſtationary, nor to be retrograde at any time.

CHAP.

CHAP. VI.

Of the true Motions of the Planets.

§. 583. THE ſun, the moon, and the primary planets, are at one time nearer the earth than at another. For, their diameter appears now greater; again leſs. The ſun is neareſt the earth, when in *Capricorn*; and moſt diſtant, when in *Cancer*. For, in the former his diameter appears biggeſt; and in the latter, ſmalleſt. *Saturn*, *Jupiter* and *Mars* are nearer the earth, when in oppoſition to the ſun, than towards the time of their conjunction. The diameter of *Mars* in his oppoſition appears eight times as large, as in his conjunction. The moon in the firſt and laſt quarter is always more diſtant from the earth than at full and new.

§. 584. The moon's path or orbit goes not round the ſun, but round the earth. For, if the moon is new; ſhe is between the ſun and the earth. But if full; the earth is between her and the ſun (§. 566. 568). And thus her orbit goes round the earth. If it went round the ſun at the ſame time, the moon in her conjunction with him could not ſtand under him, or between him and the earth. The revolution of the moon from weſt to eaſt about the earth is performed in twenty-ſeven days, ſeven hours, and forty-three minutes.

§. 585. And in this very ſpace of time the moon turns about her axis, ſhe always turning to us one and the ſame ſide. Her ſpots, indeed, which retain the ſame poſition with regard to each other, appear now to come ſomewhat nearer to the limb of her apparent diſk, but again to remove as much therefrom. From this appearance it was at firſt concluded, that the ball of the moon turned not about her axis, but was only ſubject to ſome librations; ſuch as we obſerve in a globe, whoſe centre of gravity is ſhifted. But the elder *Caſſini* held theſe librations to ariſe partly from the motion of the moon round the earth, and partly from her rotation about her axis. This thought his ſon explained at large in a diſſertation, inſerted into the memoires of the academy for the year 1729. Did the moon, in the time ſhe performs her revolution round the earth, not move about her axis, we ſhould not conſtantly obſerve one and the ſame ſide of her. This may be eaſily ſhewn, if round a point we deſcribe a circle, and along it move in a twofold manner a ball, one half white, the other black; one time without; another, with a motion about its axis. Suppoſe it at reſt in a point of the circular line, and to turn its white ſide towards its centre. If moved out of the point of reſt along the circular line, without beginning at the ſame time to twirl about its axis, it gradually turns its white ſide from the centre, and at length preſents to it the black. But if ſo moved along the circular line, as that in the time of the

motion

motion through the whole line, it is made to turn about its axis; its white ſide comes to be conſtantly turned to the centre, if turned to it at the beginning of the motion.

§. 586. *Venus* and *Mercury* move round the ſun. The earth is without both their orbits. And the orbit of *Mercury* is encompaſſed by that of *Venus*. Suppoſe the ſun in S, fig. 6. plate VIII. the earth in T, and one of thoſe planets in B, and thus in conjunction with the ſun, between him and the earth. From B the planet will remove or recede, by a certain ſpace S C, from the ſun S to C. This ſpace on the earth will appear under the angle S T C Now neither of theſe planets removes, or digreſſes from the ſun to a ſtate of oppoſition with him (§. 579). And therefore the planet goes back again from C to the ſun, till again it begins a conjunction therewith. This happens, when the planet comes to D, and the ſun ſtands between it and the earth (§. 579). After this conjunction the planet removes again out of D from the ſun by the ſpace S A, which on the earth is ſeen under the angle A T S. Out of A the planet goes to the third conjunction in B, where again it has its place between the ſun and the earth. And thus the orbits of both theſe planets go round the ſun. And as they gain no other ſituation, than that either the ſun ſtands between them and the earth, or they ſtand between the ſun and the earth; the earth is without their orbit.

Venus

Venus removes 47 at most, and *Mercury* 28 degrees from the sun. Suppose the greatest digressions or elongations of *Venus* to be S C and S A, and to be seen under the angles S T C and A T S. Those angles are greater than the angles S T F and S T G. And under these the greatest elongations S F and S G of *Mercury* from the sun will be seen. So that the orbit of *Venus* must be greater than that of *Mercury* (§. 194). *Venus* compleats her orbit in 224 days, 14 hours, 49′ 20″; and *Mercury*, in 87 days, 23 hours, 15′ 38″.

§. 587. *Saturn*, *Jupiter* and *Mars* are together called the *superior planets*, and describe their orbits round the sun and the earth. And yet the centre of those orbits is without the centre of the earth. Suppose the earth to be in T, fig. 7. plate VIII. If a superior planet is in conjunction with the sun; the sun and the planet are seen together from the earth (§. 578). But the superior planets in their conjunction with the sun appear fully enlightened on the disk they obvert to the earth. And thus if the sun is in S, the superior planet is above him in M. If therefore the superior planets move round the earth, their orbits at the same time go round the sun. But they actually move round the earth: for they are now in conjunction with, again in opposition to the sun (§. 579). If a superior planet is in the conjunction, it is, for instance, in Q, fig. 8. plate VIII. the sun in S, and the earth in T. If in opposition, it is, for instance, in P, the sun in S, and the earth again

in

in T. In the conjunction the earth is without the ſun and the planet; but in the oppoſition between the planet and the ſun. And this could not happen, did not the planet move round the earth. In the conjunction the planet is more diſtant from the earth than in the oppoſition (§. 583). And thus the centre of their orbits cannot fall in, or coincide with the centre of the earth.

Mars compleats his revolution in 686 days, 22 hours, 29 minutes: *Jupiter*, in 4332 days, 12 hours, 20′ 9″, and *Saturn*, in 10759 days, 6 hours, 36 minutes.

§. 588. The orbits of *Venus* and *Mercury*, the inferior planets, are encompaſſed by the orbits of the ſuperior. For, the inferior planets move only round the ſun; and the earth is without their orbits (§. 586). On the contrary, the ſuperior planets take their courſe as well round the ſun, as round the earth (§. 587).

§. 589. The orbit of *Mars* is encompaſſed by the orbit of *Jupiter*, and this laſt by the orbit of *Saturn*. For, *Mars*, in 1591 *January* 9, covered *Jupiter*; and *Jupiter* in 1563 covered *Saturn* from the earth. Now as the earth is within the orbits of the ſuperior planets, *Jupiter* muſt deſcribe a larger orbit than *Mars*; and *Saturn*, a larger than *Jupiter* round the earth.

§. 590. From the motion of the ſpots, obſervable in *Jupiter*, *Mars* and *Venus*, and from the return of thoſe ſpots, after having for ſome time remain-
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ed inviſible, the elder *Caſſini* concluded, that *Jupiter* turns round his axis in 9 hours, 56′; *Mars*, in 24 hours 40′, and *Venus* in 24 hours.

§. 591. The motion of the ſatellites of *Jupiter* round *Jupiter*, and of the ſatellites of *Saturn* round *Saturn*, appears hence; viz. that both theſe primary planets ſtand now between their ſatellites and the ſun, and again their ſatellites between them and the ſun. The elder *Caſſini*, who according to the teſtimony of the academy of ſciences at *Paris* had done, firſt, in 18, and then in 43 years, as much for the four ſatellites of *Jupiter*, as had ſcarce been done for the moon in 3000 years, at length found, that the firſt revolves round *Jupiter* in one day, 18 hours, 28′ 36″; the ſecond, in three days, 13 hours, 18′ 52″; the third, in ſeven days, three hours, 59′ 40″, and the fourth, in 16 days, 18 hours, 5′ 6″. As to the revolutions of the ſatellites of *Saturn* round *Saturn*, the younger *Caſſini* found the following times: For the

	d.	h.	′	″
I.	1	21	18	27
II.	2	17	41	22
III.	4	12	25	12
IV.	15	22	41	14
V.	79	7	48	0

The diſcoveries of the two *Caſſini* are contained in the *Memoires of the academy of ſciences*, &c.

SECT.

SECT. III.

Of ſuch STARS as appear but ſeldom.

CHAP. I.

Of the ſeveral Kinds of them.

§. 592. UNDER thoſe we underſtand ſuch, whoſe time of appearance is yet uncertain. And thus we muſt exclude from them the ſtar in the neck of the ſwan called χ, which now appears, again diſappears, compleating this alternation of appearance and diſappearance in $404\frac{1}{2}$ days. But the ſtars, rarely appearing, are of two ſorts. Some are fixt ſtars, as in regard to the other known and conſtant fixt ſtars, retaining always for the whole time of their appearance one and the ſame place: ſuch appears to have been the new ſtar, that was ſeen from 1572 to 1574 in *Caſſiopeia*, and at firſt ſurpaſſed the ſtars of the firſt magnitude in luſtre, but gradually turned leſs and leſs, till at length it quite diſappeared. Other rarely appearing ſtars change their place in the heavens like the planets, and are called *comets*.

CHAP.

CHAP. II.

Of Comets.

§. 593. AND then, comets yield no pure and bright light, like the fixed ſtars. This difference may be perceived, on viewing their light through good teleſcopes. In many comets we obſerve a tail, and round it a pale vapour. The comet itſelf, which ſhines brighteſt amidſt this vapour, is called the *body* or *nucleus of the comet*; the encompaſſing vapour, its *atmoſphere*; and nucleus and atmoſphere together are called its *head.* The manner, how theſe three parts, the nucleus, atmoſphere and tail appeared in the comet of 1744, Mr. profeſſor *Heinſius*, who viewed it at *Peterſburg* from *January* 5, to *February* 16, with an excellent *Gregorian* teleſcope, has diſtinctly exhibited in his deſcription of this comet, plate 1. As to the nature, motion, and effects of comets in general, there was publiſhed in 1744, at *Berlin*, a ſolid and very diſtinct anſwer to ſeveral queries on that head, together with a continuation.

§. 594. Comets, like other ſtars, ſeem to move daily from eaſt to weſt, and to riſe and ſet when their declination (§. 558.) is not greater than the height of the pole. In this caſe they remain conſtantly above the horizon; as do, for inſtance, the ſtars in the great and little bears. Beſides this common apparent motion (§. 575), they have alſo

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a proper, appearing to move from one fixed ſtar to another. This happens either from north to ſouth, or from ſouth to north; or from weſt to eaſt, or from eaſt to weſt. If a comet appears to move in the zodiack from weſt to eaſt; we ſay, that it moves in the order of the ſigns, or in conſequence, or that it is direct. Thus appeared the comet of 1680 and 1681, to move from ♑ to ♒, ♓, &c. But if the apparent motion of the comet be from eaſt to weſt; we ſay, it moves contrary to the order of the ſigns, or in antecedence, or that it is retrograde (§. 582). Thus appeared the comet of 1744 to move from ♈ to ♓. In order to explain, how theſe apparent motions ariſe with regard to our earth; we are to conſider the diſtance of a comet from the earth and the ſun, and the motion of the earth as well about her axis, as alſo round the ſun. But all this will be beſt taught below in the doctrine of the ſyſtem of the world; whither alſo we poſtpone the enquiry, whether comets are fiery and burning bodies, and how their tails ariſe.

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THE

DOCTRINE

OF THE

Syſtem of the World.

§. 595. BY the ſyſtem of the world we underſtand the connection, in which the ſolid and fluid bodies therein ſtand mutually with reſpect to each other, and by which they conſtitute the viſible world.

CHAP. I.

Of the MOTIONS of the EARTH.

§. 596. FROM the diurnal motion of the earth about her axis, proved above (§. 342. ſeq.), the common motion (§. 575.) of all the ſtars may be explained; and thus be ſuperſeded the motion of theſe laſt in 24 hours from eaſt to weſt round the earth. Suppoſe G I N H G, fig. 8. plate II. to be a circle on the earth's ſurface, and A F B L E A to repreſent a circle in the heavens. If the

ſpectator is on the earth's ſurface in G, the ſtar A appears to him in the circle of the heavens in the zenith. Now if the place G comes with the earth's motion about her axis, to I; the ſpectator ſees the ſtar F in the zenith. If the place G comes to H; the ſtar L appears in the zenith. And if at length the place G comes again to G; the ſtar A appears anew in the zenith. Now as the ſpectator is quite inſenſible of the motion of the earth about her axis; and yet one ſtar after another appears to him in the zenith: it ſhould ſeem, as if the ſtars moved contrary to him, and conſequently from eaſt to weſt (§. 486, 492).

§. 597. The other motion of the earth is the annual, moving round the ſun in 365 days, 5 hours, and 49 minutes. For, from this may be explained in an intelligible and natural manner, all what we obſerve in the apparent motions of the planets and the ſun. The ecliptick, deſcribed (§. 556), is therefore the path of the earth in her annual motion.

In general, the ſun and the planets appear to us to ſtand at the limits of the fixed ſtars, as the diſtance between a fixed ſtar and the ſun, or a planet, is diſtinguiſhable under no obſervable angle (§. 484).

The apparent motion of the ſun through the ecliptick (§. 556.) may be repreſented as follows. Suppoſe the ſun's place to be S, fig. 9. plate VIII. and the circle marked with numeral characters, the earth's path. Now if the earth is in 7; the ſun appears to be in ♎. If the earth comes to 6; the ſun appears in ♏. As therefore the earth appears to

advance

advance in her path according to the numeral characters; so the sun appears to proceed according to the signs of the ecliptick.

The moon actually moves round the earth from west to east (§. 584). But she appears to run over the zodiack, as the distance between her and each sign is seen under no sensible angle. Suppose the earth to be in S, fig. 9. plate VIII. as the centre of her orbit. Now if the moon is in 7; she appears to be in ♈. Come she to 6; she appears to be in ♉. And come she to 5; she appears to be in ♊; so that it should seem, as if she moved from the one sign to the other.

The inferior planets *Mercury* and *Venus* appear in the space of a year to move along with the sun round the earth, and towards the time of their inferior conjunction with the sun to be retrograde (§. 582). How both appearances may happen, on viewing both planets on the earth, and on this last moving round the sun, may be understood by means of fig. 1. plate IX. the earth is without the paths of the inferior planets (§. 586). And thus take she her course round the sun, her path encompasses the orbits of *Mercury* and *Venus*. The period of the earth is to that of *Mercury* as 4 to 1. For, the earth accomplishes her course in 365, and *Mercury* in 87 days (§. 586). And thus in the time, that *Mercury* finishes his whole orbit, the earth only describes a fourth of hers. Divide therefore the path of *Mercury* into 8 equal parts, and each quarter of the

earth's orbit into juſt as many parts. Now if *Mercury* is in 1, and the earth in T 1; *Mercury* appears in *a*. If the earth moves to 2, and *Mercury* alſo to 2; *Mercury* appears in *b*. And if the earth goes to 3, and *Mercury* alſo to 3; he appears in *c*. If the earth arrives at 4, and *Mercury* in like manner at 4; he appears in *d*. Hitherto he has been direct, or has appeared to run over a part of the zodiack in the order of the ſigns: but if he comes to 5, and thus is in inferior conjunction with the ſun; and the earth in her path comes to 5; *Mercury* appears in *e*, and conſequently to be retrograde. And if he goes on to 6, and the earth in her orbit to 6; he appears to have continued his retrogradation to *f*. If he comes to 7, and the earth in her path to 7; he appears in *g*, and is anew direct. If he reaches to 8, and the earth in her orbit to 8; he appears in *h*, and ſtill direct. Purſue we in imagination *Mercury* in his orbit, and the earth in hers, till this laſt have her place again in T; one ſees, how *Mercury* appears gradually to come to *i*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *x*, *y*, *z*, A, B, C D E F G, H, I, and thus in a year to run through the whole zodiack, and in the inferior conjunction with the ſun to be retrograde.

The ſuperior planets appear to be retrograde at the time they ſtand in oppoſition to the ſun (§. 582). Both appearances ariſe on the earth from her annual motion round the ſun in the following manner. The orbit of the earth is encompaſſed by the orbits of the ſuperior planets (§. 587). Suppoſe S, fig. 2. plate IX. to

to be the place of the ſun, and the circle deſcribed about him to be the orbit of the earth. As *Jupiter*, in his motion round the ſun, requires 12 times as much time, as the earth (§. 587); the orbit of the earth is to that of *Jupiter*, as 1 to 12. Divide therefore as well the earth's orbit, as alſo the twelfth part of *Jupiter*'s orbit into twelve equal parts. Suppoſe the laſt to be at A. If the earth in her orbit is in 1, and *Jupiter* in his orbit in like manner in 1; he appears in the heavens in *a*. If the earth and *Jupiter* in their orbits go on from 1 to 2; this laſt appears in the heavens in *b*. Move they on to 3; *Jupiter* appears in *c*. Come they to 4; *Jupiter* appears in *d*. And reach they to 5; *Jupiter* appears in *e*. Hitherto *Jupiter* has been direct. But now he begins to be retrograde, when in his orbit come to 6, and the earth in her orbit alſo to 6. For, now *Jupiter* appears in *f*. In this time he approaches to the oppoſition; which actually follows, when in his orbit he moves to 7, and the earth in hers alſo to 7, the earth then ſtanding between him and the ſun. In this oppoſition *Jupiter* appears in *g*, and thus has continued his retrogradation. He appears ſtill to be retrograde quite to *h*, when in his orbit he reaches the place 8, and the earth in hers the place 8. Come they both to 9; *Jupiter* appears in *i*, and conſequently again direct. In like manner it may be ſhewn, how *Saturn* and *Mars* appear to become retrograde, when in oppoſition to the ſun.

In the oppoſition the ſuperior planets are nigher the earth than in the conjunction (§. 583). For, in the conjunction the planet is in A, the ſun in S, and the earth in V (§. 578). And ſo the diſtance of the planets from the earth = A V. If the planet is in oppoſition; he is in A, and the ſun in S, and the earth between in T (§. 578). And then the diſtance of the planet from the earth = A T. The difference between A T and A V is = T V, which is the entire diameter of the earth's orbit. And thus the ſuperior planet is about this much nearer the earth in the oppoſition than in the conjunction.

The apparent retrogradations of *Jupiter* happen oftener than thoſe of *Mars*; and thoſe of *Saturn* oftener than thoſe of *Jupiter*. For the retrogradations happen in the oppoſition. And this laſt happens, when the earth approaches to a ſuperior planet. But ſhe approaches ſooner to *Jupiter* than to *Mars*; and ſtill ſooner to *Saturn* than to *Jupiter*; for, *Jupiter* moves ſlower than *Mars*, and *Saturn* ſlower than *Jupiter* (§. 587).

Jupiter employs more time in the retrogradation than *Mars*; and *Saturn* ſtill more than *Jupiter* (§. 582). And in the caſe of the motion of the earth round the ſun it can no otherwiſe be. Suppoſe *Jupiter*, for inſtance, to be in G, fig. 3. plate IX. when appearing to ſtand ſtill in his direct courſe. If the earth is in her orbit in A, where at the ſame time the ray of light falling from *Jupiter* touches the earth's orbit; on the earth *Jupiter* is ſeen in N.

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If the earth in her path goes on to the point B, where the ray of light of *Jupiter* touches the earth, when *Jupiter* concludes his apparent retrogradation; he appears to the ſpectator in O. The time therefore, in which the earth runs over the arch A B, is the time, in which *Jupiter* accompliſhes his apparent retrogradation. The orbit of *Mars* is encompaſſed by that of *Jupiter* (§. 589). If therefore *Mars* ſtars in F, ſo that from the former place of *Jupiter* G a right line may be drawn through F, and through H, the centre of the earth's orbit; the rays of light F D and F C, which from *Mars* rake the earth's orbit, cannot reach to A and B, but only to D and C. And ſo the earth muſt be in D, in order to obſerve, that *Mars*, who is in F, appears in his direct courſe to be ſtationary. And then from D one ſee *Mars* in L. Move the earth in her orbit from D to C; *Mars* appears in M. And thus *Mars* appears to the ſpectator, as if retrograde from L to M. Now the time, which the earth takes to move through the arch D C, is the time of the apparent retrogradation, which *Mars* has accompliſhed. And now as the arch D C is leſs than the arch A B; *Mars* in his retrogradation appears to have took a ſhorter time than *Jupiter*. The planets, in reality, continue their direct courſe in the time, they appear to the inhabitants of the earth to be retrograde. And thus the arches of the earth's orbit, which coincide with the apparent retrogradations, are leſs than if the planets actually ſtood. But as *Jupiter* moves ſlower than *Mars*,

Mars, and *Saturn* ſlower than *Jupiter* (§. 587); the ſaid arches of the earth's orbit are ſuch, as that the arch for *Jupiter* is greater than the arch for *Mars*; and the arch for *Saturn* greater than the arch for *Jupiter*.

From this very figure it is plain, how it comes, that *Jupiter* in his retrogradation appears to deſcribe a leſs arch than *Mars*; and *Saturn* a leſs arch than *Jupiter*. Suppoſe *Mars* to appear ſtationary in F, and *Jupiter* in G. In this manner the arch A B, which anſwers to the apparent retrogradation of *Jupiter*, is greater than the arch D C, which the earth in her orbit accompliſhes at the time, that *Mars* finiſhes his retrogradation. The half arch, which *Mars* appears to compleat in the retrogradation, is the meaſure of the half angle E H D; and the half arch, which *Jupiter* appears to deſcribe in his retrogradation, is the meaſure of the half angle E H A. And thus H G A is leſs than H F D. And therefore the moſt diſtant planet in his apparent retrogradation deſcribes a leſs arch than the nearer. But that the angle H G A is leſs than the angle H F D, may be ſeen from the following circumſtances. As G A and F D are tangents; they form with the ſemidiameters H A and H D of the earth's orbit at A and D right angles. Now if in a triangle one angle is right; the two remaining angles together make a right. And ſo the angle H F D is leſs than H D F; and H G A leſs than H A G. But the angle F H A is greater than F H D. For, the arch E A is greater

greater than the arch E D. And therefore the angle H F D is greater than the angle H G A. For, by ſo much as the angle G H A is greater than the angle F H D; by ſo much is the angle H G A leſs than the angle H F D. Otherwiſe in the triangle H D F the ſum of both the angles H F D and F H D could not be equal to the ſum of the angles H G A and G H A in the triangle H A G. For, each of theſe ſums makes 90 degrees.

§. 598. The earth moves ſo in her orbit round the ſun, that her axis remains conſtantly parallel with the axis of the world or heavens. For the height of the pole in no time of the year undergoes any change on the earth. But ſuch muſt have happened, had the earth's axis at ſeveral different times an inclination to the axis of the world, as in one place to ſtand more diſtant from it than in another. The earth's axis thus remains parallel to itſelf.

§. 599. From this it follows, that in the annual motion of the earth, her pole deſcribes a circle, and the pole of the ecliptick, marked on the earth, another circle beſides.

§. 600. If the earth moves through the ecliptick round the ſun, and if the diameter of her orbit to the diſtance of the fixt ſtars from the earth has an imperceivable ratio; the fixt ſtars has neither among themſelves, nor from our vertex, always one and the ſame diſtance. In particular, the polar ſtar muſt be differently diſtant from our vertex in the ſolſtices, from what it is in the equinoxes. Theſe

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three particulars baron *Wolfius* demonstrates in his *Elementa astronomiæ*, §. 594. in the following manner.

Let two stars A and B, fig. 4. plate IX. be taken near the eclíptick. Suppose the earth to be in C between the star A and sun S. The star A is thus in opposition to the sun (§. 578). And thus the distance of the star A from the star B appears under the angle B C A. Suppose the earth in her orbit to come to D. And so the star A is in conjunction with the sun (§. 578). And thus the distance of the star A from the star B appears under the angle B D A. Now if C D, the diameter of the earth's orbit to C A, the distance of the star A from the earth in C, have a perceivable ratio; the angle B C A is greater than the angle B D A. For, *that* is the external, and *this* the angle opposite to it in the triangle B D C. And therefore A appears to be more distant from B, when the earth is in C, than when in D.

Suppose the stars M and N, fig. 5. plate IX. to be without the ecliptick, or distant from it. If the earth is in T; they appear under the angle M T N. If on the contrary the earth is in V; they appear under the angle M V N. These two angles cannot be mutually equal in all positions of the earth. For, supposing the angle M T N to remain unchanged, and be now the star N or *n* nearer the point T, or more distant from it; the angle M V N will be greater, when the star N or *n* is more distant from the point T, than when standing nigher to it. And thus in different

different positions of the earth they have different distances from our vertex.

Suppose the pole of the world or heavens, in regard to the sun, to be in P, fig. 6. plate IX. and A C B D to denote the circle, which the pole of the earth, or of her equator describes. Suppose the pole of the ecliptick to be in M in regard to the sun, and *a b c d* to represent the circle, described by the pole of the ecliptick. The line P M denotes the distance of the pole of the ecliptick from the pole of the world and heavens. Suppose the sign of ♋ to be in A, and in B the sign of ♑; and consequently in the former the summer-solstice; and in the latter, the winter-solstice: on the contrary, in C the sign of ♈, and in D that of ♎; and consequently in *that*, the vernal equinox; and in *this*, the autumnal equinox. Suppose at length the polar star to have its place in S. If now the earth is in ♈, her pole is in C. And thus the distance of the polar star from the earth's pole = S C. But if the earth is in ♋; her pole is in A. And thus the distance of the polar star from the earth's pole = S A. But the secant is less than the secant S A, as baron *Wolfius* shews in his *Elementa geometriæ*, §. 302. And thus in the solstices the polar star must have a different distance from the vertex, from what it has in the equinoxes.

§. 601. If the earth moves round the sun, it may happen that two stars at a certain time of the year shall appear as one, and at another time of the year,

as two. Suppoſe the earth to be in T, fig. 5. plate IX. and a ſtar in N. Imagine a right line drawn from T to N. If in that line there is another ſtar *n*, either nearer to, or farther from the earth than N; on the earth we can only diſtinguiſh a ſingle ſtar, as either *n* is covered by N, or N by *n*. But if the earth comes to the place V; the ſtar N is ſeen along the line V N, and the other *n* along the line V *n*; and conſequently two ſtars. And ſo *Caſſini* has ſeen the firſt ſtar in *Aries* divided at times into two; as this was alſo obſerved in one of the heads of *Gemini*. Some other ſtars in the *Pleiades*, and the middle ſtar in the ſword of *Orion*, have at certain times appeared threefold, nay fourfold.

§. 602. From the annual motion of the earth, and from the motion of the light coming to her from the fixt ſtars a peculiar apparent motion ariſes, which Dr. *James Bradley* firſt obſerved with the greateſt accuracy in 20 ſtars, and explained in the *Philoſophical Tranſactions*, N° 406. Mr. profeſſor *Segner* in the firſt edition of his *Introduction to natural philoſophy*, §. 565 *, exhibits this motion as follows: Suppoſe A B, fig. 7. plate IX. to be ſo ſmall a part of the earth's orbit, as that it may be conſidered as a right line. Suppoſe the earth in T, and a fixt ſtar in S. If the light moves from the ſtar towards the earth T, whilſt this laſt at the ſame time advances to B; the light acts on an eye, moving at the ſame time along with the earth, juſt as if T with this eye ſtood ſtill,

* In the ſecond Edition, §. 664. ſeq.

and

and the light, besides its motion along S T, had another along S C (§. 486); the line S C being supposed to be parallel to the line A B and S C assumed so great, as is the way, which the earth has made in her orbit, while the light moves through S T. From both these motions there thus arises a compound motion along C T. The light therefore falls into the eye along this line of direction C T, and causes the star, seen by means of this light, to appear in the line C T, which with S T, in which it would appear, did the earth stand still, forms the angle S T C. In another place of her orbit if the earth, in regard to this fixt star, moves differently, and comes at length to have the direction of her motion directly opposite to the former T B, along T A. In this case C S comes to D S, and the angle S T D to lie on the other side of S T; so that the star, on account of the earth's motion, appears in the heavens to move gradually about the point S, or to swing at it to and fro, according to the different position of S with respect to the ecliptick. Now if a star stands in S, fig. 8. plate IX. so that the right line I S, connecting it with the centre of the sun S, falls almost perpendicular on the surface of the ecliptick A B C D; the star seems to describe about S a small ellipsis *a b c d*; in regard S appears in *a*, when the earth is in A; and in *b*, when the earth is gone from A to B, and so on, as the letters shew. Dr. *Bradley* found, that the greater axis of this small ellipsis,

lipsis, which is described in a year, comes to about 40′.

§. 603. The earth therefore ranks with the primary planets (§. 561).

§. 604. Her orbit encompasses the way, which *Venus* takes round the sun, and is immediately encompassed by the path, which *Mars* describes round the same. The first was shewn above (§. 586). The last is hence clear. The superior planets describe such wide circles round the sun, as that their centres are without the centre of the earth (§. 587). But among these circles that, along which *Mars* accomplishes his course, is the least (§. 589).

CHAP. II.

Of the Order or Disposition of the PLANETS and SUN.

§. 605. THE sun occupies the middlemost place in the orbits of the planets, as all of them move round him. From this place he removes not in any perceivable manner, but turns about his axis (§. 551). Next the sun, revolves *Mercury*, and after him *Venus* (§ 586); after her the earth, and after this last, *Mars* (§. 604); after *Mars*, *Jupiter*, and at lentgh after him, *Saturn* (§. 589.) Round the earth moves the moon, and along with her at the same time round the sun (§. 562). Round *Jupiter* revolve four; and round

Saturn, five ſatellites; of which *thoſe* accompany *Jupiter*; and *theſe Saturn* round the ſun (§. 597.) fig. 2. plate x.

This doctrine of the order of the planets and the ſun is called the *Copernican ſyſtem*. The motion of the earth round the ſun, which is the principal difference therein, was maintained before the birth of Chriſt by the *Pythagorean* philoſopher *Philolaus*, and after him by *Ariſtarchus* of *Samos*. After the birth of Chriſt in the 15th century Cardinal *Nicolaus Cuſanus* in his work *De docta ignorantia*, brought up anew the annual motion of the earth. At length in the 16th century this doctrine gained a peculiar regard, as explained by *Nicolaus Copernicus*, a canon in the biſhoprick of *Wermeland* in *Poland*, in his book *De revolutionibus orbium cœleſtium*. In order to have a diſtinct repreſentation of the order of the planets in their motions round the ſun, machines have ſeen deviſed, in which certain balls move in the manner of the heavenly bodies, by means of wheels, ſcrews, and pinions. *Huygens*'s deſcription of his excellent *Automaton planetarium* is well known. The *Syſtema Copernicanum*, in the phyſical cabinet of the ducheſs of *Saxe-Gotha*, *Louiſa Dorothea*, the author thereof M. *John George Bauſſe*, archdeacon in *Gotha*, has deſcribed, and exhibited in a copper plate. At *Paris* M. *Paſſemant* executed a clock, on which ſtands an ingenious *planetarium*, in which, by means of the clock-work, the planets revolve round

the ſun, and the moon round the earth, with ſuch a degree of juſtneſs, as that in two or three thouſand years not a degree's difference can poſſibly happen in the heavens. The teſtimony, which M. *Paſſemant* had from the royal academy of ſciences, *February* 11, 1749, to this purpoſe, was communicated to me in perſon by M. *Logau*, a *Sileſian* nobleman, on his return in 1750 from *Paris*, and tarrying for ſome days at *Lipſick*. On the ball of the earth, which is of copper, ſilvered over, is a general map, with the chief cities marked thereon. A circle on it conſtantly diſtinguiſhes the part, which the ſun enlightens, from the other, where it is night; ſo that at all times one ſees the cities, on which the ſun riſes, and at which he ſets; and alſo each moment what time of the day it is in each country. The ſeaſons of the year change, and the days increaſe and decreaſe according to the different poſition of places. Under one pole one ſees a night of ſix months ſucceeding each other, while the oppoſite pole enjoys a conſtant day of ſix months. The moon each month revolves about the ball of the earth, and accompanies her in her annual revolution about the ſun. The moon has her decreaſe and increaſe. And by means of a moveable circle one ſees her time of riſing and ſetting for all the places of the earth. By puſhing on a wheel, one may in a ſhort time make all the planets paſs in review before one's eyes for many centuries to come. And by this means

means may be ſeen all the future eclipſes. And if the wheel-work be made to go back, all the eclipſes, that happened for the preceding centuries.

The common opinion about the planetary ſyſtem, which prevailed till the days of *Copernicus*, was the *Ptolemaick*. *Ptolemy*, a mathematician of *Egypt*, who lived at *Alexandria* in the ſecond century, in his *Almageſt* placed the earth, as a body at reſt, in the centre, and made the moon revolve next round her; then, *Mercury*; in the third place, *Venus*; in the fourth, the ſun; in the fifth, *Mars*; in the ſixth, *Jupiter*; and in the ſeventh, *Saturn*, from eaſt to weſt. But the phænomena of the planets, as a neceſſary conſequence of the annual motion of the earth, cannot be explained by the *Ptolemaick* ſyſtem.

For this reaſon *Tycho Brahe*, who in the ſixteenth century had made himſelf famous by his aſtronomical labours, gave up the *Ptolemaick* doctrine; but as he was of the opinion, that the *Copernican* ſyſtem contradicted the ſcriptures, he deviſed a new one, fig. 3. plate x. According to him the earth is at reſt in the centre of the world, and round her move the moon, ſun, and ſphere of the fixt ſtars. About the ſun move the five planets, among which *Mercury* and *Venus* ſo continue their courſes, as never to have the earth between them and the ſun: whereas *Mars*, *Jupiter*, and *Saturn* move round the earth in their orbits. The ſun moves daily about the earth. The five planets at the ſame time with

the ſun move round her every day from eaſt to weſt. And notwithſtanding this, continue the while their proper motion about the ſun. *Gaſſendi*, who in his life of *Tycho*, book 3. delivers this doctrine, mentions on that occaſion, that *Tycho* himſelf had inſerted it in chap. 8. of his book on the comet, which he obſerved in 1577 and 1578 at *Uraniburg*. This book is the ſecond *De mundi ætherei recentioribus phænomenis.* The path of the planets goes yearly with the ſun through the zodiack. But now in order to explain the retrogradation of the planets; the *Tychonick* aſtronomers make each planet ſo to continue its motion, as in its path to deſcribe curve lines, reſembling ſpiral lines. In *Doppelmaier's Atlas cœleſtis* they are repreſented, charts 9 and 10. From among the mathematical inſtruments of the late Mr. profeſſor *Hauſen* I procured a cycloidal machine, by which the *Tychonick* motions of the planets may be imitated, which M. *Hauſen* ſome years before his death had procured out of *Denmark*.

What therefore in the ſolar and planetary ſyſtem, according to the *Copernican* doctrine, may be explained by a few rules in an eaſy manner, is in the *Tychonick* ſyſtem rendered perplexed and difficult to the underſtanding by a multiplicity of rules. And thus what reaſon can there be that we ſhould prefer the *Tychonick* to the *Copernican* ſyſtem? The laſt by no means contradicting any propoſitions of ſcripture. We may ſpeak of bodies in a twofold manner; optically, on expreſſing the phænomena, that ariſe by

the

the light in the eye; and phyſically, on ſaying what agrees to bodies, without their light acting on the eye. Both holds true. Of the ſtars the ſacred writers ſpeak optically; aſtronomers, phyſically; ſo that there is no contradiction between them; as what holds only between ſuch perſons, one of whom denies, what the other affirms of one and the ſame thing.

CHAP. III.

Of the Orbits, Diſtances, and Magnitudes of the PLANETS.

§. 606. THE earth and the other primary planets, in their motions round the ſun, deſcribe elliptick lines. In F, fig. 11. plate 11. the focus of ſuch a line, is placed the ſun. And the *radius vector* F G (§. 104), drawn from the centre of the ſun in F to that of the planet G, deſcribes in equal times equal areas: or the areas, deſcribed by it, are to each other, as the times, in which they are deſcribed. This law of the motion of the planets *Kepler* firſt diſcovered by dint of genius, and great care in making obſervations, as appears from his *Commentarii de motibus ſtellæ Martis*. Before his time aſtronomers held the planetary circles or orbits for eccentrick. But experience taught, that the calculations, made by ſuch circles, diſagreed with the phænomena of the planets. In particular, *Kepler* found, that the theory of eccentrick circles did by

no means ſuit the motion of *Mars*. A body, moving in an ellipſis, runs ever quicker, the nearer in its path it approaches to the focus; and on the contrary, ever ſlower, the more diſtant therefrom (§. 104, 105). Both theſe particulars are conſtantly obſerved in the planets.

§. 607. The point A, where the planet is neareſt the ſun in F, is called the *perihelium*: on the contrary, the point *a*, in which it is at the greateſt diſtance therefrom, the *aphelium*.

§. 608. The motion of the moon round the earth (§. 584.) happens, according to *Kepler*'s doctrine, in an ellipſis; in whoſe focus F is the earth, fig. 11. plate 11. The point A, where the moon is neareſt the earth in F, is called her *perigæum*; and the point *a*, where ſhe is at the greateſt diſtance from the earth, her *apogæum*.

§. 609. The right line A *a*, drawn from the leaſt diſtance of a planet from the focus F to its greateſt diſtance, is called the *line of the apſides*: the diſtance of the focus F from the centre of the ellipſis C is called the *eccentricity*: and the line, drawn from the centre of the ſun, or of a primary planet in F, to the elliptick path of a primary or ſecondary planet, is called the *diſtance*. In *a* the planet has the greateſt, and in A the leaſt diſtance. That diſtance, which is exceeded by the greateſt about ſo much, as this exceeds the leaſt, is called the *mean diſtance*. For inſtance, if F *a* = 61, and F A = 53; the mean is equal 57. It is found, ſo you halve the ſum of the greateſt and leaſt. If with the ſemi-axis C *a* a circle

be

be deſcribed through the aphelion *a*, and perihelion A, it is called the *eccentrick circle*. Suppoſe a planet to be for inſtance in *o*, let a line, from the centre of the planet in *o*, be drawn perpendicular to the line of the apſides A *a*, and produced from *o* to the point K of the eccentrick circle, juſt now mentioned: the arch K *a* of the eccentrick circle between the point K, at which it is interſected by the ſaid perpendicular line, and between the point *a* in the line of the apſides, is called the *eccentrick anomaly*.

§. 610. The ſatellites of *Jupiter* and *Saturn* move by juſt the very ſame laws, by which the primary planets deſcribe their elliptick orbits.

§. 611. According to *Caſſini*, the greateſt diſtance of the moon is = 61; the mean = 57, and the leaſt = 53 ſemidiameters of the earth.

The diſtances of the moon from the earth are found by means of her parallax (§. 485). Suppoſe the moon, for inſtance, in her orbit to be in S, fig. 16. plate VII. The moon, obſerved by a ſpectator, on the earth's ſurface in E, appears in the heavens to be in C. But to a ſpectator, ſuppoſed to be at the centre of the earth in T, ſhe would appear at the ſame time to be in the heavens at B. The place B is called the *true optical*; and C, the *apparent optical place*; the diſtance between both places, the parallax of altitude; and the angle C S B, to which the angle T S E is equal, the parallactick angle, and ſometimes the parallax itſelf. Now if together with this angle S, fig. 13. plate VII. the

height of the moon above the horizon S R is known; the diſtance of the moon from the earth may be found, as follows: If you deduct the height S R from the quadrant R Z; there remains the arch S Z, which is the meaſure of the angle Z A S. In the triangle A S T there are thus three known quantities: the quantity of the ſide A T, the ſemi-diameter of the earth; the quantity of the angle S, which repreſents the parallax; and the angle Z A S, whoſe ſine may be taken for the ſine of the obtuſe angle S A T in the triangle. And thus the concluſion is as follows: As the logarithm of the ſine of the angle A S T, to the logarithm of A T; ſo is the logarithm of the ſine of the angle Z A S to the logarithm of T S. This logarithm found ſhews in the tables the line T S, the diſtance of the moon from the earth.

At preſent attempts are making for finding the moon's parallax, in ſo far as it is taken in a general ſenſe, on obſerving the moon at the ſame time at two different places on the earth's ſurface. In this ſenſe, the parallax is an angle, formed by two lines, imagined to be drawn by two obſervers from two different places on the earth's ſurface to the moon. *France* has choſen Meſs. *de la Caille* and *de la Lande* to be ſuch obſervers. The firſt ſet out from *Paris October* 21, 1750, for the cape of *Good Hope*, where he arrived *April* 29, 1751. The laſt aſtronomer in ſome months after departed for *Berlin*, with the intention of obſerving the moon there

there at the ſame time; in order to be able to determine her parallax, and by that means her diſtance from the earth, more accurately. This diſtance has, indeed, in our day been already ſo far determined, as that we may aſſume its quantity without apprehending a miſtake therein of even 1000 miles. And ſuch a miſtake or error is to be deemed inconſiderable, when we reflect, that the mean diſtance of the moon from the earth amounts to 50000 *German* miles. But it has been attempted ſo to diminiſh this miſtake or error, as to be only 100, nay 50 miles only. The moon, in her diſtance, is at an inacceſſible height. In order to meaſure ſuch a height, a baſe is pitched upon, at whoſe extremities a ſeveral perſon looks upwards, and imagines lines to be drawn from theſe extremities. So that a triangle ariſes, in whoſe vertex is the height. The baſe, and the angles thereat, are meaſured. Now if the baſe is not too ſmall againſt the diſtance of the height; it may be found from the three known parts of the triangle with perfect juſtneſs. Now in order to have a baſe of ſufficient magnitude in the triangle, in whoſe vertex is the moon; for the one ſtation the cape of *Good Hope* was choſen, ſo diſtant from another ſtation in *Europe*, as that the lines, imagined to be drawn from both places to the moon, might with each other form at her a conſiderable angle. Then again, the meridian of the cape, in regard to the parts of *Europe* has a very commodious poſition. For, it paſſes through

Cracow

Cracow in *Poland*, and through *Upſal* in *Sweden*, and through other places; or, at a very ſmall diſtance along ſuch places, where ſkilful aſtronomers, furniſhed with proper inſtruments, might make juſt obſervations, favouring M. *de la Caille*'s labours. For, in all places, which this meridian touches, the moon culminates at the ſame time, or at the ſame time paſſes through it. Alſo did an obſerver of the culminating moon in *Europe* happen to be without the meridian of the cape of *Good Hope*; his obſervations might be ſo advantageouſly altered and adjuſted, as that they might paſs for obſervations, made under the very ſame meridian. The arch of the meridian between *Berlin* and the ſaid cape contains 86° 16′ or 1294 *German* miles. If in the courſe of obſerving from both thoſe places ſo far diſtant aſunder lines are ſuppoſed to be drawn to the moon; there ariſes, indeed, a mixt triangle; as the baſe between both the ſtations is an arch of a circle: ſo that there appears an obſtruction to interpoſe to the menſuration of the moon's diſtance: but it may be eaſily removed. As inſtead of the arch of 86° 16′ we need only take its chord, which is 1176 *German* miles long. Only the queſtion is, how we are to meaſure the angles at this baſe? The common practical geometry can afford no aſſiſtance in this caſe; we cannot from the one ſtation ſee the other, the ſurface of the earth being convex, and *Berlin* by much too diſtant from the cape of *Good Hope*. But in that caſe aſtronomy is not without her reſources.

At

At *Berlin* on a certain day, when the moon culminates, the angle is meaſured, under which the appearing moon is diſtant at *Berlin* from the zenith; and from the quantity of this angle the quantity of the angle may be known, which the line, drawn from *Berlin* to the culminating moon, forms with the baſe at *Berlin*. In like manner may the angle be found at the other extremity of the baſe at the cape of *Good Hope*. But yet it is not to be denied, but that notwithſtanding the uſe of the beſt inſtruments, an error of ſome ſeconds may ſteal in, which, in determining the diſtance of the moon from the earth, cauſes a conſiderable error. Hence another reſource is taken up, in order to avoid this danger. We meaſure the angle, formed at the moon by both the lines, imagined to be drawn to her from both the ſtations, and called her parallax. If this angle is meaſured with the greateſt accuracy, one of the angles at the baſe may be omitted in the calculation, and on account of the other, in determining the moon's diſtance from the earth we have no conſiderable error to apprehend, were even the true quantity of this other angle at the baſe meaſured not perfectly ſo accurate. But in order to find the angle at the moon, or her parallax, the following operation is to be made. Both obſervers, in one and the ſame culmination, muſt obſerve at once one and the ſame fixt ſtar, and meaſure its apparent diſtance from one and the ſame limb of the moon by means of a micrometer. For, be two places on the earth's

earth's ſurface never ſo diſtant aſunder; yet two obſervers therein ſee one and the ſame fixt ſtar in one and the ſame place in the heavens, on viewing it at the ſame time. But if theſe two perſons obſerve the moon at the ſame time; ſhe appears to each in a different place. And thus the one obſerver will perceive the moon at a leſs; and the other, at a greater diſtance from the fixt ſtar. Suppoſe the fixt ſtar to be in A, fig. 16. plate VII. and one obſerver to ſee the moon in C; and the other, in B; the apparent diſtance C A of the moon from the fixt ſtar would be greater than her apparent diſtance B A from the ſame ſtar. And deducting B A from C A, the remaining arch C B gives the parallax, and conſequently the meaſure of the angle at the moon at S. The operations of both the aſtronomers, the one at *Berlin*, and the other at the cape of *Good Hope*, obſerving the moon, conſiſted therefore in this. Both of them, in one the ſame culmination of the moon, obſerved one and the ſame fixt ſtar, in the direction of the meridian. Each of them with an inſtrument inveſtigated at the ſame time the apparent diſtance of this fixt ſtar from one and the ſame limb of the moon. And one of them meaſured an angle at the baſe.

This is the notion, which Mr. profeſſor *Heinſius*, in a publick diſcourſe, pronounced in the philoſophical hall at *Lipſick* on *February* 24, 1752, gave of the moſt principal operations, undertaken at two ſo diſtant places, as *Berlin* and the cape of *Good*

Hope,

Hope, for the more accurately determining the moon's parallax. M. *de la Lande* has deſcribed the obſervations he made at *Berlin* in the memoires of the *Berlin* academy T. 6. in two memoires p. 236--279, and p. 379—411.

§. 612. According to *Caſſini*'s calculation the greateſt diſtance of the earth from the ſun is = 22374; the mean = 22000, and the leaſt = 21626 ſemidiameters of the earth.

The diſtance of the earth from the ſun may be found, on knowing the diſtance of the moon from the earth, and her elongation from the ſun. Suppoſe the earth in T, fig. 15. plate VII. the moon in L, and the ſun in S. In the triangle L T S the angle at L which the line S L forms with the ſemidiameter of the moon's orbit, is a right angle. The angle at T has the elongation of the moon for its meaſure. Deducting the ſum of both theſe angles from 180, there remains the angle at S. And therefore we have three known quantities. And thus we form the following concluſion. As the ſine of the angle S to the diſtance T L of the moon; ſo is the ſine total of the angle at L, to the the line T S, the diſtance of the earth from the ſun.

§. 613. We allow the mean diſtance of the earth from the ſun, or the ſemidiameter of her eccentrick circle, 1000 equal parts. In ſuch parts in general, we compare together and determine the diſtances of the planets from the ſun, as *Graveſande* ſhews in his *Elementa mathematica phyſices*, §. 954--963.

963. The mean diſtance of *Mercury* is 387; of *Venus*, 723; of *Mars*, 1524; of *Jupiter*, 5201; and of *Saturn*, 9538. The greateſt diſtances are found, on adding to the mean diſtance of each ſeveral planet its eccentricity, and the leaſt diſtance on deducting the eccentricity. The eccentricity of *Saturn* is 547; of *Jupiter*, 250; of *Mars*, 141; of the earth; 169; of *Venus*, 5; and of *Mercury*, 80. For inſtance, the mean diſtance of *Saturn* is 9538. If to this you add the eccentricity 547, the greateſt diſtance is 10085. But if from the ſaid mean diſtance you deduct the eccentricity, the leaſt diſtance is 8991.

If the mean diſtances are divided by 100; the mean diſtance of *Saturn* will be 95; of *Jupiter*, 52; of *Mars*, 15; of the earth, 10; of *Venus*, 7; and of *Mercury*, almoſt 4.

§. 614. In ſemidiameters of the earth the mean diſtance of the earth from the ſun contains 22000 (§. 612). The mean diſtances of the planets in ſemidiameters of the earth are found by the rule of three. For, as the mean diſtance of the earth is in general to the mean diſtance of a planet in 1000 parts; ſo the mean diſtance of the earth is to the mean diſtance of a planet in ſemidiameters of the earth. In theſe parts therefore the mean diſtance of *Saturn* is 209836; of *Jupiter*, 114400; of *Mars*, 33528; of *Venus*, 15906, and of *Mercury*, 8514.

The greateſt and leaſt diſtances in ſemidiameters of the earth we find by the rule of three. We in ge-

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neral compare in each planet its mean diſtance as well with its greateſt, as alſo with its leaſt (§. 613); then we take its mean diſtance in ſemidiameters of the earth; and at length from theſe three numbers ſeek the fourth, as the greateſt or leaſt diſtance in ſemidiameters of the earth. For inſtance, the greateſt diſtance of *Saturn* amounts to 221870. For

9538 : 10085 : : 209836 : 221870.

The diſtances of the planets from the earth in ſemidiameters thereof are, according to *Caſſini*, of the following quantities.

	Greateſt.	Mean.	Leaſt diſtance.
♄	244000	210000	176000
♃	143000	115000	87000
♂	59000	33500	8000
♀	38000	22000	6000
☿	33000	22000	11000

According to *Caſſini*'s calculation, the firſt ſatellite is diſtant from *Jupiter* $5\frac{2}{3}$; the ſecond, 9; the third, $14\frac{23}{60}$, and the fourth, $25\frac{3}{10}$ jovial ſemidiameters. The diſtances of the ſatellites of *Saturn* are expreſſed in diameters of his ring. The diſtance of the firſt is in ſuch diameters $1\frac{19}{20}$; of the ſecond, $2\frac{1}{2}$; of the third, $3\frac{1}{2}$; of the fourth, 8; and of the fifth, 24.

§. 615. The times, in which the planets finiſh their courſe in their orbits round the ſun, are ſuch, that their ſquares are to each other, as the cubes of the diſtances from the ſun. For inſtance, *Saturn* accompliſhes his period almoſt in 30 years, and *Jupiter*

piter in 12. The ſquare of 30 is 900; and of 12, 144 (§. 587). The diſtance of *Saturn* to that of *Jupiter*, is as 95 to 52 (§. 613). The cube of 95 is 857375; and of 52, 140608. This laſt is to the firſt as 1 to 6; and juſt ſuch is the proportion of the ſquare 144 to the ſquare 900.

The ſatellites of *Jupiter* and *Saturn* accompliſh their revolutions round them in like manner in ſuch times, whoſe ſquares are to each other, as the cubes of the diſtances, at which theſe ſatellites are removed from their primary planets.

§. 616. In order to compare the ſurfaces and magnitudes of the ſun and planets with the ſurface and magnitude of the earth; we are in the firſt place to enquire into the ratio of their diameters to the diameter of the earth. For, ſpheres are to each other, as the cubes; and their ſurfaces, as the ſquares of their diameters.

The diameter of the moon to the diameter of the earth, is as 1 to 4 nearly. Suppoſe the moon to be in S, fig. 16. plate VII. and E T to repreſent the ſemidiameter of the earth. The moon viewed from E and T, the angle C S B is the parallactick angle, and C B the meaſure of the parallax. The angle T S E is equal to the parallactick; for, both are vertical angles. And thus if a ſpectator in the moon viewed the earth's ſemidiameter T E; it would appear as big to him, as would on the earth the moon's parallax C B, on viewing the moon from T and E. We may therefore take the parallax of the

moon

moon for the apparent ſemidiameter of the earth, and conſequently ſay: As the parallax of the moon, or the angle which the apparent ſemidiameter of the earth ſubtends at the moon, is to the apparent ſemidiameter of the moon; ſo is the true ſemidiameter of the earth, to the true ſemidiameter of the moon. Her parallax in her leaſt diſtance is $1° 1' 25'' = 3685''$, and her apparent ſemidiameter $16' 21'' = 981''$. And thus the ſemidiameter of the earth is to the ſemidiameter of the moon, as 3685 to 981. But the ſemidiameters of two ſpheres are to each other as the diameters. And therefore if 981 was contained four times compleatly in 3685; the ſurface of the moon would be to that of the earth, as 1 to 16, and her magnitude or ſolid contents to that of the earth, as 1 to 64.

The diameter of the earth is to the diameter of the ſun, as 1 to 152 $\frac{1}{2}$. Suppoſe the ſun to be in S, fig. 16. plate VII. To a ſpectator in the ſun, viewing the earth's ſemidiameter T E, it would appear as large, as his parallax to one, viewing him from T and E. And thus we may put the ſun's parallax for the apparent ſemidiameter of the earth at the ſun, and conclude in the foregoing manner: as the parallax of the ſun, or the apparent ſemidiameter of the earth at the ſun, to the apparent ſemidiameter of the ſun; ſo is the true ſemidiameter of the earth to the true ſemidiameter of the ſun. The ſun's parallax at his mean diſtance is $6''$, and his apparent ſemidiameter $15' 15'' = 915''$. And thus the true

diameter of the earth is to the true diameter of the ſun, as 6 to 915, that is, as 1 to 152 ½, on dividing both numbers by 6. And therefore the ſurface of the earth is to the ſurface of the ſun, as 1 to 23104; and the ſolid contents of the earth to the ſolid contents of the ſun, or their magnitudes to each other, are as 1 to 3,511,808. Out of the ſun therefore above three millions of earths might be formed.

The diameters, ſurfaces, and magnitudes of the inferior and ſuperior planets, are to the diameter, ſurface, and magnitude, or ſolid contents of the ſun, in the following ratio.

	The diameter to the diameter ☉.	The ſurface to the ſurface ☉.	Magnitude to the magnitude ☉.
Ring	11 : 37		
♄	5 : 37	1 : 55	1 : 405
♃	2 : 11	1 : 30	1 : 166
♂	1 : 166	1 : 27556	1 : 4574296
♀	1 : 84	1 : 7056	1 : 592704
☿	8 : 290	1 : 84100	1 : 24389000

In order to diſcover what ratio the diameter of a planet has to that of the ſun: we muſt enquire, how large the ſemidiameter as well of the planet, as alſo of the ſun would appear, were planet and ſun viewed at one and the ſame diſtance from the earth. Suppoſe the earth in O, fig. 3. plate v. the ſemidiameter of the planet to be A D, and of the ſun A *f*. As planet and ſun appear as diſks; the ray of light O A, coming from the centre of theſe diſks to the eye, ſtands perpendicular on A D and A *f*. But O A

O A is at the ſame time the diſtance, at which one ſees as well A D as A *f*. Deſcribe we a circle with this diſtance; this diſtance is a ſine total, and the lines A D and A *f* are tangents of the angles A O D and A O *f*, under which A D and A *f* are ſeen. The ſaid angles are called the apparent magnitudes of the true A D and A *f* (§. 193). The tangents of theſe apparent magnitudes are to each other, as their true magnitudes A D and A *f*. The true ſemidiameter A D of the planet is thus to the true ſemidiameter A *f* of the ſun, as the apparent ſemidiameter A O D of the planet to the apparent ſemidiameter A O *f* of the ſun. Now if it be aſked, how to find, how great the ſemidiameter of a planet would appear, when viewed at the diſtance of the ſun from the earth? The apparent magnitudes, which are only a few minutes, are in the inverſe ratio of their diſtances, as baron *Wolfius* has ſhewn in his *Elementa Optices*, §. 212. And thus the apparent diameter of the planet, to the apparent diameter of the ſun, is inverſely as the diſtance of the ſun to the diſtance of the planet from the earth. For inſtance, the mean diſtance of the ſun is to the mean diſtance of *Jupiter* from the earth, as 22000 to 115000, that is, as 1 to 5. The apparent diameter of *Jupiter*, according to *Huygens*, is $= 64''$. And thus if *Jupiter* ſtood in the place of the ſun, his apparent diameter would be $320''$. For, 1 : 5 : : 64 : 320. The apparent diameter of the ſun, according to *Kepler*, is $1830''$. And therefore the true diameter of *Jupiter* is to the

true diameter of the ſun, as 320 to 1830, that is, as 2 to 11, on dividing both numbers by 160.

As the ſun's ſemidiameter is equal to 152 ſemidiameters of the earth; the ſemidiameter of *Saturn* amounts to $20\frac{20}{37}$; of his ring, $45\frac{7}{37}$; of *Jupiter*, $27\frac{7}{11}$; of *Mars*, $\frac{76}{83}$; of *Venus*, $1\frac{17}{21}$; and of *Mercury*, $\frac{76}{145}$. For, as the ſemidiameter of the ſun to the ſemidiameter of a planet in general; ſo is the ſemidiameter of the ſun in ſemidiameters of the earth, to the ſemidiameter of the planet in ſemidiameters of the earth. For inſtance, the ſemidiameter of the ſun is to the ſemidiameter of *Saturn* in general, as 37 to 5. Conſequently, $37 : 5 :: 152 : 20\frac{20}{37}$.

CHAP. IV.

Of the Forces, by which the PLANETS continue in their Orbits.

§. 617. THE primary planets could not move round the ſun, nor the ſecondary, or ſatellites, round their primary planets, were not the primary planets conſtantly retracted, or drawn back (§. 100.) to the ſun, and the ſecondary to the primary, by a centripetal force, out of the right line, in which they ſeek to run off by a centrifugal force: This centripetal force is the very ſame with gravity (§. 17. 91). And thus the planets are retained in their elliptical orbits (§ 606.) by gravity.

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The ſquares of the periodical times of the planets are to each other, as the cubes of their mean diſtances §. 615). This is a property of the bodies, whoſe centripetal forces, by which they continue in their orbits round a centre, are to each other inverſely as the ſquares of their diſtances §. 109). Now as the *vis centripeta* and gravity are one and the ſame thing; it is thence clear, that the gravity of the primary planets towards the ſun, and of the ſecondary towards their primary planets muſt decreaſe, as the ſquares of the diſtances of the firſt from the ſun, and of the laſt from their primary planets increaſe.

In an arch, which the moon deſcribes in a minute of time, ſhe approaches to the centre of the earth by a ſpace, equal to that, through which a body at the earth's ſurface falls in a ſecond by virtue of its gravity. This may be known in the following manner: The moon finiſhes her orbit in 39343 minutes of time (§. 584). And thus the arch, ſhe deſcribes in a minute of time, amounts to 33 ſeconds of the circle, as conſiſting of 1296000 ſeconds. Suppoſe this arch to be L C, fig. 4. plate x. and the centre of the earth T. Had the moon no centripetal force, or gravity towards the earth, but was impelled by the bare centrifugal force only; in the minute, in which ſhe runs over the arch L C, ſhe would come in the line L B to B; and thus at the end of the minute be diſtant from C, and conſequently from the centre of the earth T, by a ſpace equal to the line B C. But ſhe deſcribes the arch L C, and in it at the end of the minute reaches the place C. So

that ſhe has approached to the centre of the earth by a ſpace, equal to the line B C. Now drawing parallel to B L the line C D, and to B C the line L D; L D is equal to B C. And therefore L D expreſſes the ſpace, through which the moon in a minute approaches to the centre T of the earth. If this approach happens along this ſpace by virtue of gravity; the minute in which the moon at L falls thro' the ſpace L D, muſt be to the time, in which on the earth's ſurface at A ſhe would fall thro' an equal ſpace, as the greater diſtance T L from the centre of the earth in T, to the leſs diſtance T A (§. 334). We will ſuppoſe with *Newton* in his *Principia*, lib. 3. prop. 4. the mean diſtance of the moon to be 60 ſemidiameters of the earth: And thus T L to T A as 60 to 1. If therefore the moon falls in a minute by virtue of gravity through the ſpace L D; this minute muſt be to the time, in which on the earth's ſurface ſhe would fall through an equal ſpace, as 60 to 1; that is, as a minute to a ſecond. And thus the ſpace L D muſt amount to 15 *Paris* feet. For, ſo far a body falls in the firſt ſecond on the earth's ſurface by virtue of its gravity (§. 34). The ſpace L D, through which the moon in a minute, on finiſhing the arch L C, approaches the earth's centre, is actually ſo big. For, we find the line L D, on dividing the ſquare of the ſmall arch L C, which the moon accompliſhes in a minute of time, by the diameter E L of the moon's orbit (§. 107, n. 1). And according to *Picart*'s menſuration allowing 19615800 *Paris* feet to a ſemidiameter of

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the earth; E L the diameter of the moon's orbit contains 2353896000 ſuch parts; and conſequently the periphery of the orbit, 7391233440. If this number is divided by 39343 minutes, in which the moon deſcribes this periphery; the quotient 187871 is the arch L C, which the moon runs over in a minute. The ſquare of which is 35295512641; which divided by the diameter 2353896000; the quotient gives 15 feet for L D. From this it evidently appears, that the force, which impels the moon to the centre of the earth, and thus retains her in her orbit, is one and the ſame thing with gravity.

In like manner M. *Glume* in his diſſertation *De gravitate univerſali*, §. 149. ſhews, that the earth in a minute of time, on deſcribing the arch L C of 5154957 feet, recedes from the right line L B, which by the *vis centrifuga* alone ſhe can finiſh in a minute of time, through the ſpace B C or L D about 30 $\frac{10}{12}$ feet, and by this comes ſo much nearer to the ſun.

CHAP. V.

Of the mutual Actions of the SUN and PLANETS on each other.

§. 618. THE earth gravitates towards the moon; *Jupiter*, towards his ſatellites; and *Saturn*, towards his; and the ſun towards the primary planets. For, if the moon by her gravity acts againſt the earth, the earth acts againſt her with

equal intenſeneſs or force (§. 8). Actions equally intenſe may be explained from one and the ſame force. As thus the moon in her diſtance from the earth gravitates towards the earth; ſo alſo does the earth in her diſtance from the moon towards the moon. In like manner may the proof be formed for the gravity of *Jupiter*, *Saturn*, and the ſun.

§. 619. The ſun and each primary planet therefore remain by this means united together, ſo that theſe laſt gravitate towards the ſun, and the ſun towards the primary planets. And by this very means each primary planet remains connected with its ſatellites or moons.

When two bodies A and B by their gravity act reciprocally on each other; and conſequently A has a tendency to fall to B, and B to A; it is juſt the ſame thing, as if A was attracted by B, and B by A. And hence the gravity, with which they act on each other, is called the *attraction* (§. 58).

§. 620. And in this caſe the earth ſhould be moved out of her place, when the moon has now a leſs, again a greater diſtance from her: And for the very ſame reaſon the ſun alſo ſhould be moved out of his place. For, when two bodies A and C, fig. 2. plate 1. gravitate reciprocally towards each other, and remain together mutually connected: it is juſt as much, as if by means of a rigid line A B C they acted on each other from the points A and C, at which they may be diſturbed, and ſo united their gravity in a common centre B, that the weight

of

of the body A to that of C was inverſely as the diſtance C B from the common centre of gravity B, to the diſtance A B from the ſame. For, in this manner the bodies A and C, would be equiponderant (§. 21). Suppoſe the earth in A, and her moon in C; and A B to repreſent the diſtance of the earth, and B C that of the moon, from their common centre of gravity: ſuppoſing the common centre B of gravity to remain at reſt; and the moon to move from C towards D; the earth muſt move out of A towards E, for both bodies to continue equiponderant. If the earth is in C, and the ſun in A; and if the earth moves out of C towards D; the ſun muſt move out of A towards E. But yet no change of place can be obſerved either in the earth, in regard to her moon; or in the ſun, in regard to the earth and the other planets. The reaſon of which is to be ſought for in the magnitude of the maſſes of the ſun and earth, and in the ſmall diſtance of the common centre of gravity from the centre of the ſun. The earth and moon remain equiponderant; if, for inſtance, the maſs of the earth in A, to that of the moon in C, is inverſely as B C the diſtance of the moon from B, to A B the diſtance of the earth from B. Now if the moon removes from C towards D; the earth, to be ſure, muſt alſo move out of A towards E. But as the diſtance of the moon out of C towards D is to her firſt diſtance B C; ſo muſt alſo the diſtance of the earth out of A towards E, be to her firſt diſtance

A B.

A B. For inſtance, ſuppoſe C B to A B as three feet to one foot; and the body in C to remove out of C $\frac{3}{10}$ foot towards D: the diſtance of the body in A out of A towards E muſt amount to $\frac{1}{10}$ only. For $1\frac{1}{10} : 3\frac{3}{10} :: 1 : 3$. If the body moves out of C towards B $\frac{3}{10}$ foot, the other body A need only approach $\frac{1}{10}$ foot towards B. Now the leſs the diſtance B is from the centre of the body A, and the greater number of times the maſs of the body A exceeds that of the body C, the more indiſcernable the ſpace, through which the body A approaches to the point B, when C approaches thereto; or removes from B, ſo C removes from B. The common centre of gravity of the moon and earth may be diſtant not above a diameter of the earth from the earth's centre. *Newton* in his *Principia*, lib. 3. prop. 12. ſhews, that the common centre of gravity of *Jupiter* and the ſun is a little way without the ſurface of this laſt; and the common centre of gravity of *Saturn* and the ſun a little way within the ſurface of the ſun. And ſhould, ſays he, the planets all together come to ſtand on one ſide of the ſun in a line, one after another, their and the ſun's common centre of gravity would be ſcarce an intire diameter of the ſun diſtant from the centre of the ſun. Now if this common centre of gravity, proceeds he, is conſtantly at reſt; the ſun, indeed, would, according to the different poſitions of the planets towards every ſide, be moved, but never recede far from the ſaid centre of gravity. We have therefore,

therefore, reaſon to hold the common centre of gravity of the earth, ſun, and planets for the centre of the ſolar and planetary ſyſtem. For, as theſe inceſſantly move towards each other by their gravity; their centres, which in like manner are in motion, can by no means be held for the quieſcent centre of the ſolar and planetary ſyſtem. And would we place a body, againſt which all bodies act the moſt intenſely with their gravity, in this centre; this preference would be due to the ſun. But as the ſun moves, we muſt pitch upon a quieſcent point for the ſaid centre, from which the centre of the ſun is the leaſt diſtant. The ſun would remove ſtill leſs from it, were he only denſer and larger, ſo as to be ſubject to a leſs degree of motion.

§. 621. As each moon or ſatellite with its primary planet, remains conſtantly connected by virtue of the gravity, with which they reciprocally act on each other; they are both to be conſidered as parts of a ſingle body. Now if a part A of a body C gravitates towards another body D, alſo B the other part of the body C gravitates towards D. And conſequently the moon and each ſatellite of *Jupiter* and *Saturn* acts with its gravity againſt the ſun, and again the ſun with his gravity againſt the moon and the ſatellites of *Jupiter* and *Saturn*.

If the gravity of the moon towards the ſun was conſtantly equal; ſhe would, by the gravity towards the earth, ever deſcribe one and the ſame line round the earth. But her gravity or attraction towards the

ſun

ſun is now greater, again leſs. Whence there enſue in her courſe round the earth many inequalities, whereby the curve lines, which at different times ſhe compleats round the ſun, come to differ from each other. For inſtance, ſuppoſe the ſun to be in S, fig. 1. plate x. and the earth in T, and A L B I to repreſent the moon's orbit. If the moon is in L, or in the conjunction; ſhe is nigher the ſun, than when in A. In L therefore ſhe has a leſs degree of gravity towards the earth T than in A in the quadrature. And thus her motion is quicker in L than in A. In like manner her gravity will be weaker towards the earth, and conſequently her motion quicker, when ſhe is in I, or in the oppoſition, than when in the quadrature in A or B. For, as the earth T is nearer the ſun than the moon in I; the gravity of the earth towards the moon will be by ſo much leſſened, as it is increaſed towards the ſun. In like manner alſo on the other hand the gravity of the moon towards the earth undergoes a decreaſe. The manifold deviations, which the ſun by his gravity towards the moon ever produces in her orbit, which without the action of his gravity ſhe would take round the earth, are deſcribed in *Newton*'s *Principia* lib. 3. prop. 22. and in *Graveſande*'s *Elementa phyſices*, T. 2. c. 16. The academy of ſciences at *Peterſburg* in 1750, appointed a prize of 100 ducats for the beſt anſwer to the queſtion; viz. Whether all the inequalities, obſervable in the motion of the moon are conformable to the *Newtonian* ſyſtem or no

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And which is the beſt theory to account for theſe inequalities? in order to determine the place of the moon for any particular time. M *Clairaut* gained this prize. His writing came out under the title; *Theorie de la lune, deduite de ſeul principe de l'attraction, reciproquement proportionelle aux quarrés des diſtances.* Therein he ſhews, that all the inequalites in the motion of the moon may be perfectly well explained from the attractive force alone, which is inverſely as the ſquares of the diſtances, and conſequently that no correction is requiſite in the *Newtonian* theory; a thing that had hitherto been called in queſtion by almoſt all aſtronomers.

From obſervations it is known that the moon's nodes (§. 577.) move retrograde or in antecedence. This happens through the attraction or force, wherewith the ſun impels the moon out of the plane of her orbit, when ſhe is without the quadratures, and the line of the nodes is without the conjunction and oppoſition of the moon with the ſun. For, if the line of the nodes N *n* has this poſition, fig. 5. plate x. it paſſes through the ſun, on being produced. But thus the ſun is in the plane of the moon's orbit, and thus muſt needs attract the moon in this orbit. And thus ſhe cannot be driven out of it by him. If the moon is in the quadrature; for inſtance, in A, fig. 1. plate x. the ſun acts on her and on the eareh by equal diſtances S A and S T, and conſequently with equal forces. And in this manner the forces, with which the moon and earth act on

on each other, continue in the ratio they would have, did the ſun not act on them at all. And thus the moon retains in A the place, by virtue of gravity allotted to her, wherewith ſhe and the earth act reciprocally on each other. But if the moon is without the quadrature; for inſtance, in F, between the quadrature B and the conjunction L; ſhe will be more intenſely attracted to the ſun S, than the earth to the ſame. For, F S, along which ſhe is attracted to the ſun, is leſs than T S, along which the earth gravitates towards the ſun. And ſo ſhe will be forced out of the place of her orbit, which ſhe would hold, were ſhe not expoſed to the ſun's attraction. And now we may conceive, how by ſuch attraction of the ſun the moon's nodes come to move retrograde. Suppoſe P *p*, fig. 6. plate x. to be the plane of the ecliptick, and P A the moon's orbit. If the moon is in A, and has thus removed ſome way from the nodes; ſhe will be forced in ſuch a manner from the plane of her orbit by the ſun's attraction, as that in the following point of time not to take her courſe along the line A B, along which the path P A proceeds, but through A *b*. And thus ſhe comes nearer by ſo much to the plane of the ecliptick than the line B *b* amounts to. So that ſhe has a motion, as if ſhe came from the retrograde diſtant node *p*. And ſo long as ſhe thus continues her courſe, and removes from the node; ſhe ſeems to come from a node ever more diſtant. And in this manner the nodes move retrograde.

§. 622

§. 622. From the force, with which ſun and moon act on the earth, the receſſion of the equinoxes (§. 559.) and conſequently the retrogradation of the equinoctial points contrary to the order of the ſigns, which amounts yearly to 50″, may be explained. The equinoctial points are the two points of the ſigns of *Aries* and *Libra*, in which the eclip-tick is interſected by the celeſtial equator. Properly the earth moves in the ecliptick, and coming into either of theſe two points, the equinox, or the equality of day and night, happens. Now the vernal equinox yearly precedes, that is, happens each year ſomewhat ſooner than it did the foregoing year. The celeſtial equator therefore is every year interſected by the path of the earth, or the ecliptick, ſooner than it was the preceding year. And ſo the vernal equinoctial point is each year more weſterly than the foregoing year. Now how this ariſes from the action of the ſun and moon on the earth, may be explained juſt as was the retrogradation of the moon's nodes.

Suppoſing different moons at equal diſtances from the earth moved round her in equal times in a plane, inclined to the ecliptick, as is the plane of the moon's orbit. Theſe moons, therefore, would together have one and the ſame motion. Suppoſing, there were ſo many of them, as to be in mutual contact, and together to form a ring, conſiſting of cohering parts. This ring would thus, juſt as the moon's orbit does, interſect the ecliptick in two

points,

points, diſtant 180° aſunder. Suppoſe P*p*, fig. 6. plate x. to be part of the ecliptick, and P A a portion of the ring. The part of the ring in P is therefore, as the moon, in the node. The other part of the ring in A is diſtant from the node. Now if the ſun by his gravity or attraction acts on the part of the ring at A, it will be moved out of its place. But as one part of the ring ever coheres with the other; the whole ring will be moved out of its poſition. And thus did it before interſect the ecliptick in P, it will now interſect the ecliptick in *p*. And conſequently the node of the ring goes back from P to *p*. With a like ring the earth is encompaſſed in her equator (§. 338). As this ring of the earth's equator is nearer to the ſun and moon than the reſt of the ſurface of the earth; ſun and moon act ſtronger on the equator than on the other parts of the earth. If therefore the earth is without the equinoctical points, the ring of the earth's equator, whoſe plane interſects the plane of the ecliptick, by the attraction of the oppoſite ſun, or of the oppoſite moon, will be brought into a ſtate of flexure; ſo as that the plane of the ring, and conſequently the plane of the earth's equator, ſhall interſect the plane of the ecliptick in a point, which retrocedes to the weſt from the point, in which theſe planes would mutually interſect, had the equator no ſuch ring or bend. As ſuch retrogreſſion of the point, in which the ecliptick is interſected by the equator, is ever continually happening during the entire progreſs of the

the earth; the ecliptick, or path of the earth, in the vernal equinox muſt interſect the celeſtial equator in a point, which is ſtill ſomewhat retrograde from the point, in which this interſection happened the year before in the vernal equinox. In like manner the interſection, by which the autumnal equinox ariſes, muſt happen in a point, which is retrograde from the point, wherein the equator was the year before interſected in the autumnal equinox by the ecliptick. For, the point of the autumnal equinox is always 180° diſtant from the point of the vernal equinox. And thus the equinoctial points go backwards, or retrocede.

Newton in his *Principia*, lib. 3. prop. 39. ſhews, that the equinoxes have a yearly retrogreſſion of $9'' \, 7''' \, 20^{iv}$ by the force of the ſun, and of $40'' \, 52''' \, 52^{iv}$ by the force of the moon. The ſum of which is $50'' \, 00''' \, 12^{iv}$; the moon acting ſtronger on the earth, as being uncommonly nearer to her than the ſun.

§. 623. Now as the courſe of the earth through the ecliptick is not perceived; it muſt neceſſarily appear to the eye, as if the ſigns of the ecliptick and the other fixt ſtars advanced, or had a progreſſion from weſt to eaſt (§. 559).

As the equinoctical points retrocede, the axis of the earth muſt have ſuch a motion too. And thus if produced to the apparent limits of the heavens, it in time ever paſſes through different fixt ſtars, which ſtand farther to the weſt. And thus the extremities

of the axis of the earth, that is, the poles of the world, deſcribe round the poles of the ecliptick a circle from eaſt to weſt. The poles of the world are diſtant $23^\circ\ 28'\ 20''$ from the poles of the ecliptick. Now as the poles of the world gradually paſs through all the points, which have the ſaid diſtance from the poles of the ecliptick; the fixt ſtars in theſe points come gradually nigher to the poles of the world. And thus the poles of the world and the equinoctical points finiſh their circle from eaſt to weſt in 25920 years (§. 559, 560).

§. 624. And as all the planets gravitate towards the ſun; we may conſider them as parts of a ſingle body. The coheſion of the parts ariſes from their equal action on each other (§. 5). Which is juſt the ſame, as if they gravitated towards each other (§. 17). And ſo we may alſo appropriate to the planets a gravity towards each other. An evident example of which *Jupiter* and *Saturn* afford. When both theſe planets are neareſt to each other; *Saturn* is obſervably moved out of its path. *Graveſande* in his *Elementa Phyſices*, §. 1269—1271. ſhews, that *Jupiter* by his action on *Saturn* increaſes his gravity towards the ſun about $\frac{1}{214}$ particle; and thence *Saturn* and the ſun mutually approach nearer about $\frac{1}{130}$ particle, or ſmall part. *Saturn* alſo changes the path of *Jupiter* round the ſun, when neareſt to him. But this change is not ſo conſiderable. The changes in the paths or orbits of the other planets are ſtill far leſs. *Jupiter* cauſes the greateſt change, as being the

greateſt

greateſt planet (§. 616). *Flamſtead* obſerved, that *Jupiter* alſo diſturbs the ſatellites of *Saturn* in their motion, as attracting them a little to himſelf.

CHAP. VI.

Of the Action of the Sun and Moon on the Water and Atmoſphere of the Earth.

§. 625. AS the earth gravitates towards the ſun and the moon (§. 617); the ſurface of the ocean in the places, over which both theſe bodies come to have their poſition, riſe up towards them. This alſo would happen in the caſe of fixt bodies, were not the mutual coheſion of their parts ſtronger than the gravity towards the ſun and moon. From this gravity, we are therefore to explain all that is remarkable about the tides, recounted above (§. 363). The nigher a part of the ſea is to the moon, the more it gravitates towards her. And thus if the moon L, fig. 2. plate VIII. is over Z; the water there has a greater conatus or tendency towards her, than the water at H and R. And conſequently the water in Z muſt be more elevated than in H and R. The water in N has a leſs conatus towards the moon ſtanding over Z, than the water in H and R. And conſequently the water in H riſes by the centrifugal force, which the motion of the earth round her axis communicates thereto

 (§. 342).

(§. 342). If the moon is in the equator; the flood or tide is greater than in her declination. For, in the equator the water is nearer to the moon, than in the declination from the equator. If in autumn and ſpring the moon is full or new; the flood riſes not only higher than in the quarter moons in autumn or ſpring, but alſo higher than at the time of new and full moon in the ſolſtices. The reaſons are two; the firſt, the circumſtances of the new and full moon. In the new moon, ſun and moon are together or in conjunction (§. 562. 566). Now as the earth gravitates towards both; ſo the water has a tendency as well under the moon and ſun in Z, as alſo in H and R towards both bodies. But if the moon be diſtant about a quater of the heavens from the ſun; as for inſtance, the moon being over Z, and the ſun over R; the water in Z loſes not only of its tendency, which at the time of the new moon it has at the ſame time towards the ſun; but it is alſo in ſome meaſure weakened in the tendency to fall or riſe towards the moon, when the water in R has a conatus to riſe towards the ſun. In the full moon, ſun and moon, indeed, are diſtant aſunder 180°. Suppoſe, for inſtance, the moon to be over Z, and the ſun over N. But if the ſun ſtands over N; the water, which ſwells or heaves in N by the mentioned *vis centrifuga*, acquires by means of the gravity and tendency towards the ſun an additional ſwelling. And at the ſame time alſo the ſwelling of the water is increaſed towards the moon in Z; as now,

now, the ſun being over N, there accrues to it that degree, by which it was diminiſhed, as the ſun ſtood over R. The ſecond reaſon, why the flood riſes higher in harveſt and ſpring, at the time of new and full moon, than in the ſolſtices, is, that then ſun and moon ſtand over the equator.

Newton in his *Principia*, lib. 3. prop. 36, 37. and *Graveſande* in his *Elementa*, §. 1421, 1422. ſhew, that the water of the ocean, by the action of the ſun, is raiſed to 2, by the action of the moon, to 9, and by the action of both together to 11 or 12 feet high. And if it riſes higher in certain places (§. 363); that is owing to the flood or tide taking its way through narrow and ſhallow places; in which it cannot ſufficiently ſpread or diffuſe itſelf, as it may in deep, free, and open places.

When two bodies, an electrical and unelectrical, act on each other; they have a conatus or tendency to approach to each other (§. 250). They alſo actually come nearer to each other, if not impeded by another and ſtronger force. And thus happens in them juſt what happens in bodies, that have a gravity or an attraction towards each other. If, therefore, either the moon, or the earth, was ſo ſtrongly electrified, as that their electrical matters acted on each other; the gravity or attraction, from which ebb and flood are explained, would be an effect of electricity. For exhibiting ſuch a flood and ebb, in the beginning of the year 1752 I cauſed to be executed the following machine. On a board *a b c*, fig. 1,

plate XI. a tin veſſel *d e f g* ſtands full of water. At both ends of the board are inſerted perpendicularly two pillars *h h*: at each pillar externally a ſmall oblong narrow ſlip of board *i k*, by means of a ſcrew *m*, may be puſhed up and down in a groove or channel. Through each of theſe little boards a blue ſilk ſtring *n* paſſes. At both theſe ſtrings *n* and *n*, which are ſtrung, between the pillars *h* and *h* hangs a ſquare ſmooth rod *o p* of iron. At the one end of it *o* is a round box *q*, encloſing a ſpring. Further, at the rod there is a moveable braſs curſor *r s*, at one of whoſe ends *u* a ſtring *u t* is bound to the ſpring, and at the other end *x* a ſtring *x y*, which goes through the pillar *h* to the right hand, and through the ſhiver *k* with the ſcrew *m*. By this laſt ſtring the braſs curſor *r s* may be freely drawn to the right hand pillar *h*. And forbearing to draw; the curſor *r s*, by means of the ſtring *u t*, will be drawn by the ſpring in the box *q* back to the left hand pillar. On the middle of the braſs curſor *r s* there is underneath a little, hollowed, braſs pillar α β; in whoſe cavity may lodge a little round pillar γ, to which a copper ball A is ſoldered, and it may be faſtened down with the little ſcrew δ. This ball exhibits the moon. Round the little rod *o p*, for inſtance, at the ſpring-box *q*, a metal chain is flung, and the electricity communicated thereto. So ſoon as this happens; the water under the ball riſes up, and forms a cone ε. And if by means of the ſtring *x y* you pull along leiſurely this ball to the right hand pillar

pillar *h*; the raiſed water, over which the ball hung, ſinks down; and the following water, over which the ball comes, riſes towards it. This ſinking and riſing produces in the water, which repreſents the ſea, very obſervable waves. The diſtance of the ball from the ſurface of the water may be a half, nay a whole inch, according as the electricity is ſtrong or weak. The riſing water-cone turns not only ſtill bigger and higher, the more the electricity is heightened, but alſo increaſes in compaſs and in height, on either approaching the ball to the ſurface of the water, or inſtead of a ſmall ball ſticking on a larger. And you even need only ſtick on a piece of a great ball, ſuch as that exhibited at B. And the balls need only be hollow. As by the weight of quite ſolid balls the metal curſor *r s* would rub too hard at the rod *o p*, and conſequently not be pulled to and fro ſufficiently free. In order to diſpoſe the ball, that every where, whitherſoever it is pulled, it may have an equal diſtance from the ſurface of the water, the pillars *h* and *h*, are cut through, for the ſtrings *n* and *n* and *x y* to riſe and fall unhindered in them, on ſcrewing up or down the ſlider to which they are faſtened, by means of ſcrews. If any chaff happens to lie on the water, it floats towards the raiſed water-cone. From which we ſee, that even the water in the veſſel at a diſtance therefrom, has a draught or tendency towards the part, on which the electricity acts.

§. 626. Alſo in the earth's atmoſphere there is a conſtant alternation of ebb and flood; as the air, with the things floating therein, have juſt as well a gravity towards ſun and moon, as the water has. And thus the air ſwelling up towards ſun and moon muſt propagate this motion at the ſame time from eaſt to weſt round the earth, juſt as ſun and moon appear to move round it. M. *Alembert* in his *Reflexions ſur la cauſe generale des Vents*, art. 39 and 48, explains the conſtant morning breeze under the line between the tropicks (§. 383.) from the bare attraction of the ſun and moon. A great part of the changes of the weather is therefore to be aſcribed to the ebb and flood, produced in our atmoſphere, while earth and moon act on each other. Dr. *Kratzenſtein* in his *Diſſertation on the influence of the moon on the weather and on human bodies*, has explained all this with much probability. If, for inſtance, in the the air at Z, fig. 2. plate VIII. there is flood, when the moon ſtands over that place; the air moves from the neighbourhood, for inſtance, from H towards Z. If the air in H is filled or impregnated with a quantity of vapours; the clouds may move on from H to Z.

§. 627. The atmoſphere of the earth is ſometimes filled with vapours from the atmoſphere of the ſun (§. 552). From theſe vapours M. *Mairan*, in his diſſertation *De l'aurore boreale*, explains the origin of the northern light. It reſts on thoſe two principal enquiries, viz. whether the ſolar atmoſphere ever expands

pands ſo far at times, as that its vapours mix with the atmoſphere of the earth; and whether the circumſtances of the *aurora borealis* are of ſuch a nature, as to give ſuſpicion to look for the matters, from which they ariſe, in the atmoſphere of the ſun? Both are explained in the ſaid book with a good deal of probability. Mr. profeſſor *Heinſius* has given a diſtinct abſtract thereof in his remarks on the *Peteſburg* literary news for the years 1739 and 1740, which I ſhall here adopt. The atmoſphere of the ſun, or the matter of the zodiacal light, extends at ſome times quite to the earth, and at many times beyond the limits of her orbit. The orbit of *Venus* lies nearer to that of the earth, than the orbit of *Mercury* (§. 586); the angle S T C, fig. 6. plate VIII. under which the diſtance or elongation of *Venus* S C from the ſun, being greater than the angle S T F, under which the diſtance of *Mercury* from the ſun appears. Suppoſe the vertex or point of the zodiacal light was at a certain time ſeen in F; and at another in C: at the time, in which it would appear in C, it would be nearer to the orbit of the earth, than at the time, it would appear in F. The angle S T F, under which the greateſt diſtance of *Mercury* from the ſun is ſeen, amounts to 28°; and the angle S T C, under which the greateſt diſtance or elongation of *Venus* from the ſun appears, 47°. Did, therefore, the diſtance of the vertex of the zodiacal light from the ſun amount to ſtill more degrees; the ſolar atmoſphere would be ſtill nearer to the orbit of

of the earth. The length of the zodiacal light has at times been found 90, and at times 100 and more degrees. If the diſtance of a body from the ſun amounts to 90°; it is as diſtant from him as our earth. Suppoſe the circle T F Y to be the earth's orbit round the ſun S, fig. 2. plate XI. H R to be the horizon, and C P the line, in which the ſun is under the horizon. If there is a body in the earth's orbit at G, that may be ſeen on the earth at T along the line T G D; it forms with the line T S, which may be drawn from the earth to the ſun, a right angle at T, or an angle of 90 degrees. As the line G S, which may be drawn from G, the place of the body in the earth's orbit, to the ſun S, forms with T S at S an infinitely ſmall angle; the angle alſo at G is a right angle, or of 90°. G S forms with T S at S an infinitely ſmall angle; as T G, the meaſure of this angle, is an infinitely ſmall arch. For, as G is ſeen in the earth's orbit; which is a periphery of a circle, from the earth T, which is itſelf in this orbit; T G, in compariſonof the entire orbit, or periphery, muſt be ſo ſmall an arch, as that it may be conſidered as a right line. For, from one point to another one can only ſee along a right line (§. 144. 186). Now as the angle at T is the meaſure of the diſtance of the body in G from S; ſo alſo is the angle at G the meaſure of the diſtance of the earth in T from S. And thus the body in G is ſo diſtant from the ſun S, as the earth in T. For, one right angle is always equal to another.

other. When therefore the diſtance of the zodiacal light from the ſun is ſeen under an angle of 90°; it has one and the ſame diſtance with the earth from the ſun, or it is in her orbit. And thus if it ſtands more diſtant from the ſun than 90 degrees; the atmoſphere of the ſun extends beyond the earth's orbit. The only query is, how to find the angle, by whoſe magnitude to eſtimate the diſtance of the zodiacal light. You obſerve at what fixt ſtar the point of the zodiacal light may be ſeen. Suppoſe the ſtar to be D. Now the place of the ecliptick is known, in which the ſun, at the time of the obſervation of this light, appears, for inſtance, L. And ſo we find the arch between the ſtar D, and the place of the ſun L, and conſequently the meaſure of the angle at T, formed by the lines D T and L T. If the point of the zodiacal light ſeen was at the ſtar V, and was the place of the ſun in the ecliptick L; the arch V L would be the meaſure of the angle at T, formed by the lines V T and L T. Did the point of the zodiacal light appear at the ſtar I, and was the apparent place of the ſun in L; the arch I L would be the meaſure of the angle, formed at T by the lines I T and L T. Now if the arch is above 90 degrees, the ſolar atmoſphere is diffuſed all over the earth's orbit; and thus encompaſſes the earth, and fills or repleniſhes with its matter the terreſtrial atmoſphere. This laſt may happen, ſo the atmoſphere only extend to the moon's orbit. For, as the moon in her orbit has a greater degree of gravity to-

wards the earth than towards the ſun; all other matters alſo, which come ſo near the earth, as the moon is to her, muſt have a fall or tendency towards her. Had the moon no conſtant, laſting centrifugal force, by which ſhe moves every moment ſo diſtant from the earth, as the moon approaches to her by the action of gravity; ſhe would by her fall or tendency ſoon reach the earth. So ſoon as the matters of the ſolar atmoſphere, which ſpread themſelves quite to the moon's orbit, acquire a greater degree of gravity towards the earth, than they have towards the ſun; they become, indeed, parts of the earth, and, like the moon, and the earth's atmoſphere, acquire by the rotation of the earth, or her turning round her axis, a centrifugal force (§. 93), whereby they have a tendency to proceed in a right line, and thus to remove from the earth. But the force, whereby they are driven beyond the limits, in which they had an equiponderancy towards ſun and earth, ſo heightens their gravity towards the earth, as to be greater than the centrifugal force, which the earth's rotation communicates to them. And ſo they muſt ſink ever deeper towards the earth. The atmoſphere of the earth turns along with her from weſt to eaſt; and therefore gravitates more towards the poles than towards the equator (§. 372). So that the exhalations, forcing out of the ſolar atmoſphere into that of the earth over the equator, go towards the pole. And thus the earth's atmoſphere at the poles will be far

more

more plenteoufly replenifhed with folar vapours, than the atmofphere under the equator. For, the air at the poles is not only enriched with vapours, as the air under the equator, immediately from the fun's atmofphere, but alfo by the flow of the air from the equator. The deeper therefore the earth with her atmofphere plunges into the folar atmofphere, and the longer this lafts, and the denfer the folar atmofphere, the denfer will the earth's atmofphere at the poles prove thereby, and the more obfervable phænomena and motions may arife therein from this commixture. So long as the vapours of the fun appertain to his atmofphere, and appear to us under the form of the zodiacal light, they enlighten. In this cafe therefore they are either light of themfelves, or are enlightened by the fun. If light of themfelves, and reaching to our atmofphere, they form a fiery aerial appearance. But fuch alfo, as are not light of themfelves, may produce fuch an appearance, when of the nature of thofe matters, which either by commixing with other matters produce a flame; or take fire from the free air acting on them. Some exhalations may be coarfer; others, finer. And thus by the firft, at the horizon a vaporous fubftance may arife. In the northern light, or the light, which at times in the night takes its rife towards the north, the following circumftances manifeft themthemfelves. 1. The forerunners or prognofticks of a compleat *aurora borealis*, or northern fhine, are certain vapours at the northern horizon, not unlike a thick

thick miſt, ſeen at a diſtance. 2. Theſe vapours ſo ſpread themſelves gradually, as to form over the northern horizon a circular arch, which towards eaſt and weſt appears to ſtand on the horizon. Theſe vapours exhibit the ſegment of a circle, whoſe chord is the northern horizon: this vaporous circle may be called the *dark ſegment*. Round the arch appears a whitiſh light. The arch therefore is called the *bright arch*, and oftentimes is coloured. The bright ſtars may be diſtinguiſhed as well thro' the dark ſegment as through the bright arch. 3. Out of the dark ſegment bright pillars, rays, or ſtreamers ſeem to ſhoot upwards, and many times to reach quite to the zenith, and by their poſition to ſtand upright on the horizon, alſo often to have this poſition on the arch of the dark ſegment. Theſe rays are moſtly white, yellowiſh, or greeniſh about the part of their origin at the limb or edge of the dark ſegment. Whereas on high they are of an orange colour, which gains more or leſs of the colour of fire. 4. Up and down in the heavens bright and whitiſh clouds ariſe, but which laſt not long, yet often aſſume a fiery, ſometimes a blood-red colour. Some of theſe clouds appear and diſappear, ſo quick, as not to be unlike flaſhes of lightening. At times the entire body or maſs of the *aurora borealis* appears as if throughout in a tremulous motion: nay many times juſt as if fiery waves rolled quite up to the heavens. 5. The northern light appears greateſt when the rays, mounting up from all

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ſides of the horizon form near the zenith, as it were, a crown, all the motions of the northern light ſeeming to run together towards this place. This crown often exhibits the lantern of a cupola, and the keyſtone of an arch, where the vouſſoirs or wedges of the arch join together. At one time it appears as a ſlight circular opening, through which the heavens appear between the light and coloured clouds. Again, it reſembles the picture of an open radiating heaven. At times this crown appears more than once. In northern lights, which are imperfect, ſome of the mentioned phænomena are wanting. And thus one often ſees a northern ſhine with a dark ſegment, bright arch, and ſome rays, or ſtreamers, without flaſhes of lightening, tremulous motion and crown. In ſome again one ſees rays, or ſtreamers, without a dark ſegment and light arch having before made their appearance.

Now the query is, what may be found in theſe mentioned appearances of the northern lights to induce one, with M. *Marian* to look for their origin in the vapours of the ſolar atmoſphere? There are principally three circumſtances, which admit of no explication from the vapours of our terreſtrial atmoſphere only, viz. the height, the place, and the ſeaſon of the *aurora borealis*, or northern ſhine. The bright arch in a northern ſhine ſtands at a place, that lies nearer to the north pole, higher above the horizon, than at another place, which is more diſtant from the north pole. For inſtance, when a northern

ſhine

ſhine is ſeen at the ſame time at *Peterſburg* and at *Conſtantinople*; at *Peterſburg* the bright arch is higher above the horizon than at *Conſtantinople.* The reaſon whereof is the roundneſs or ſphericity of the earth. Now if one has meaſured at both places the height of the bright arch above the horizon with an inſtrument; from the difference of theſe heights, and from the known diſtance of both places, where the obſervation was made, one may determine the true height of the bright arch above the earth's ſurface by a calculation according to the rules, by which the diſtance of the moon from the earth is ſought for (§. 611). In this manner M. *Mairan* found the height of the northern light generally 120 *German* miles, and at times greater ſtill. The vapours, in which the ſolar rays are reflected, riſe about 10 miles high above the ſurface of the earth (§. 427.) The height, which the vapours, riſing out of the earth, reach to, is thus too ſmall to account for the height of the northern light. The inhabitants of the northern parts obſerve theſe lights only in the northern part of the heavens. And though at times they may be ſeen in other parts of the heavens, alſo commonly to incline a little way from the north to the weſt, nay many times to fill the whole heavens; yet the northern part of the heavens, in regard to the inhabitants of the countries lying towards the north pole, remains to be the proper place of the northern light. Alſo if at many times ſuch a light appears at firſt in other places of the

the heavens; yet it draws to the north, and there takes its period. Whence alſo the northern lights are rarer in *Germany* and *France*, than at *Peterſburg*, in *Sweden* and in *Norway*. Whence then comes this, were the northern lights produced from the bare vapours of our terreſtrial atmoſphere? Are theſe vapours in leſs quantity in the air over *Germany*, *France*, *Italy*, and *Spain*, than in the parts of the atmoſphere nearer the north pole? Are warmer regions to be leſs fruitful in vapours, from whoſe commixture an accenſion or a coruſcation ariſes, than the cold? If it be ſaid that they are driven towards the north pole, the *vis centrifuga* of the atmoſphere being ſtronger towards the equator than towards the pole; let the reaſon be ſhewn, why they firſt begin to ſhine, when approaching towards the north pole? As to the ſeaſon of the year, the northern lights appear moſt plentifully about the time of the equinoxes, yet more plentiful about the autumnal than vernal equinox. In general it has been obſerved, that the number of northern lights is greater in the four laſt months of the year than in the four firſt; but feweſt of all in the four middle, from *May* to *Auguſt*. And yet has not the earth's atmoſphere in theſe months the greateſt quantity of vapours, from which thunder ſtorms ariſe? And how ſhould thus the atmoſphere of the earth have in this time ſo ſmall a ſtock of vapours, by whoſe commixture a weak coruſcation might be excited? But ſo little as the queries about the ſeaſon of the year,

the part of the heavens, and the height of the northern light admit of an anſwer; if one were to deduce the reaſons from the bare vapours of the atmoſphere of the earth: ſo diſtinct, on the other hand, is the explication, on taking into the conſideration the atmoſphere of the ſun, mixing with that of the earth. As the former at times not only encompaſſes the earth; but alſo ſinks down its vapours thereinto, when only reaching to the moon's orbit; it is eaſy to conceive, that in a height of a hundred or more miles a ſhining, or gleam may ariſe from them. One might be apt to fall into the notion, that the height of a northern light might well extend to a thouſand or more miles diſtance from the earth, if the matters for it came down from the atmoſphere of the ſun. But, there is wanting in ſo great a diſtance from the earth the due denſity for a northern light, which the exhalations, ſevered from the atmoſphere of the ſun, acquire in a certain proximity of the earth, from their continuing to collect more and more therein. This collection happens principally towards the north pole of the earth, and in the greateſt plenty about it, as was ſhewn above. From this it appears, why in the northern regions, the phænomenon, called a northern light, has its ſituation in the north quarter of the heavens. Towards the ſouth pole we can obſerve no light, reſembling a northern light, as the ſouth pole lies concealed to us under the horizon. The connection of the northern ſhine with a certain ſeaſon of the year is

grounded

grounded partly on the proximity of the ſun, partly on the earth's annual motion round the ſun, partly on the poſition of the ſolar atmoſphere. In winter the ſun is nearer the earth than in ſummer (§. 583). And thus the atmoſphere of the ſun in winter may ſooner reach to our earth, and conſequently in winter produce northern lights in greater plenty in our atmoſphere than in ſummer. The earth moves in the ecliptick. In this too is moſtly found the ſun's atmoſphere. And thus the earth muſt paſs through the ſun's atmoſphere, like a ſhip through water. The fore part of a ſhip is the moſt oppoſed to the water, which it muſt divide. The fore part of our earth is thus the moſt plunged in the ſun's atmoſphere, and thus the moſt repleniſhed with vapours from the ſame; eſpecially as theſe vapours, ſo ſoon as they come to be in proximity to our earth, acquire a gravity or tendency towards her, and thus muſt fall into her the ſhorteſt way, conſequently towards her fore part. The axis of our earth is inclined to the ecliptick under an angle of 66 ½ degrees, and we may conſider both the poles as two things, one of which may repreſent the fore; the other, the hinder part. When the earth moves out of *Capricorn* towards the beginning of *Cancer* thro' the aſcending ſigns of the ecliptick; the north pole in this motion precedes, and thus plunges the moſt into the ſolar atmoſphere: whereas the earth advancing out of *Cancer* towards *Capricorn* through the deſcending ſigns of the ecliptick; the ſouth pole of the

the earth is the fore part, and this will be the moſt filled with vapours from the ſolar atmoſphere. In the firſt caſe, the ſun ſeems to move through the oppoſite ſigns, namely out of *Cancer* through *Leo*, &c. towards *Capricorn:* whereas in the ſecond caſe, to go out of *Capricorn* towards *Cancer*. And thus in the firſt caſe, from the ſummer ſolſtice till towards the winter ſolſtice, the north pole of our earth is the fore part; whereas from the winter ſolſtice till towards the ſummer ſolſtice, the ſouth pole of our earth is the fore part. The firſt happens from *June* till *December*; the ſecond, from *December* till *June*. And as thus from *June* till *December* the north pole of our earth is more plenteouſly filled with vapours from the ſolar atmoſphere than at another time: ſo alſo the northern lights muſt be ſeen oftener in the laſt half of the year than in the firſt. Now though, indeed, the north pole of our earth, as being the fore part, is oppoſed from *June* till *December* to the ſun's atmoſphere, yet its immerſion thereinto is not at all times equally great. The more the ſun's declination changes, the more the north pole immerges or plunges into it. Now as this happens about the autumnal equinox, one plainly ſees, that our northern light is the moſt copiouſly furniſhed with vapours from the ſolar atmoſphere about the autumnal equinox, and conſequently about this time the northern lights muſt appear the moſt plentifully. The contrary happens about the vernal equinox, at which time the ſouth pole of the earth has inſinuated itſelf the

the moſt into the ſolar atmoſphere. The ſolar atmoſphere is not compleatly in the ecliptick. For, as the ſun's equator now recedes to the north, again to the ſouth from the ecliptick; this alſo happens to the point or vertex of the zodiacal light. If the equator of the ſun recedes from the ecliptick to the north; alſo the point of the zodiacal light has its diſtance from the ecliptick northwards. On the contrary, it lies ſouthward, when the equator of the ſun declines from the ecliptick ſouthward. In this manner the line, going from the point of the zodiacal light to the ſun's centre, is in his equator. If the breadth of the zodiacal light continues to encreaſe conſtantly from its point towards the ſun; it appears from this, that the atmoſphere of the ſun is denſeſt under his equator, or extends wideſt at the ſun, and from the equator to the ſun's poles conſtantly decreaſes in denſity. This is owing to the ſun's atmoſphere revolving with him round his axis, and conſequently round the equator raiſed to a certain degree of height. And thus the ſolar atmoſphere has the form of a very convex glaſs on both ſides. The edge of which is about the equator, and goes directly to the eye. But both the convex ſurfaces are turned away from the eye, and are about the pole of the ſun. Now as the atmoſphere of the ſun with his equator recedes from the ecliptick; the earth in her annual motion, which happens in the ecliptick, cannot at all times plunge equally deep into the ſolar atmoſphere. This can happen the moſt at thoſe places, in which the ſolar atmoſphere croſſes the

ecliptick. The ſolar atmoſphere inclines to the ecliptick under an angle of 7 ½ degrees, and interſects it in two oppoſite points; viz. in the 8th degree of *Gemini*, and in the 8th degree of *Sagittarius*. From this reaſon our air is more plentifully than otherwiſe charged with vapours from the ſolar atmoſphere, when the earth moves through the ſigns of *Gemini* and *Sagittarius*, which happens in the months of *November* and *May*. And thus alſo about this time the northern lights muſt appear more plentifully than at any other time.

And thus we may from the deſcent of the ſolar vapours into our atmoſphere give quite natural anſwers to the following queries: as why the northern lights ſtand higher by far than the vapours mounting up from the earth: why the north is the proper place in which, in the northern countries, the north lights are obſerved; and why in a certain ſeaſon of the year they appear more plentiful than in another? But from the ſaid ſolar vapours, we may alſo explain the remaining circumſtances, and what is otherwiſe remarkable about the northern lights. Their matter, which collects from the ſolar atmoſphere about the north pole at a height of 100 or more miles, forms there, as it were, a ſpheroidal hood or dome about our earth. An inhabitant under the north pole, would obſerve this hood directly over him, and ſee its extremities run parallel with his horizon. And if this obſerver travelled from the north pole ſouthwards, his northern horizon would

would begin to cover a piece of this hood: and the farther he removed from the pole, would cover a larger portion of it. In theſe countries, as at *Peterſburg*, *Lipſick*, we lie pretty diſtant from the north pole; and therefore too can obſerve but a ſmall ſegment of the ſaid ſpheroidal hood above the northern horizon, its greater part lying concealed under it. From this it very eaſily appears, whence the dark ſegment and bright arch of a northern ſhine may take its riſe. The ſegment of the ſpheroidal hood above the northern horizon appears in the places, that are pretty diſtant from the north pole, under the form of the ſegment of a circle, whoſe baſe is the horizon, but the arch raiſed over it. The lower parts of the matter, forming this ſegment, or thoſe lying nearer the horizon, are denſe and unenlightened; whereas the higher are ſubtler and on fire. Now as theſe laſt, on the ſcore of their greater height, ſeem to encompaſs the firſt quite round above the earth; we muſt needs obſerve at the northern horizon a dark ſegment, and about that a bright arch. If at a ſtill greater height above the earth there is matter extant, which is ſet on fire, and if in the falling down it joins the matter of the ſpheroidal hood; another bright arch muſt appear; which, at a greater height above the horizon, appears to be parallel with the firſt. And ſo alſo one may repreſent to himſelf the production of a third bright arch, which at times, yet but ſeldom, makes its appearance in an *aurora borealis*. A northern light takes

its beginning ſoon after twilight, and declines from north to weſt. The reaſon whereof is as follows: The matter of the ſolar atmoſphere may fall as well in the day-time as in the night into our air, and there produce northern lights. Thoſe, that ariſe in the day-time, cannot be ſeen on account of the ſtrong day-light. The matter, which produces theſe, has all the day long ſufficient time to fall down fully into our atmoſphere, and to collect nearly towards the north, and there to ſpread itſelf abroad; ſo that then in the northern lights which we obſerve in the night, it takes no ſhare. But if the ſun is haſtening to ſet; the weſterly part of the earth is oppoſed to the ſun, and conſequently the weſterly part of our air is the moſt ſtocked with vapours from the ſolar atmoſphere. During the twilight they have time to fall down into our air, to take fire, and to make a beginning for a northern ſhine; and which thus ſoon after twilight muſt appear in the weſterly quarter. But if in time theſe vapours fall deeper down into our air, and collect towards the north; it is eaſy to conceive, why the northern ſhine appears with the growing night to draw more and more towards the northerly part of the heavens. If other vapours follow thoſe, which, towards the end of the twilight, produce the dark ſegment and the bright arch; by this increaſe the northern ſhine will gradually turn greater. Now ſuppoſing, that theſe vapours, in falling down into our air, acquired the form of a pillar or pyramid; if the denſer vapours

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ſink down quicker, and the more ſubtle, ſlower, and others conſtantly follow them, ſo thereby the appearance of a bright pillar would ariſe; if theſe vapours, by mixing with our air are either actually kindled, or at leaſt enlightened by the already kindled matter of the northern light. Such a pillar of vapour falls, in the direction of heavy bodies, perpendicular on our earth. Whence alſo it appears to us to ſtand perpendicular on the horizon. But as ſuch a pillar of vapour alſo partakes in the diurnal motion of the air, and conſequently is driven towards the north pole; ſo alſo ſuch a pillar may appear to us to be directed towards the north pole of the earth, or ſet upright on the bright arch of the northern light. Yet an accidental collection of the matter in another direction may alſo cauſe the appearance of a pillar, having a poſition different from the former. If many ſuch pillars of vapour hurry down into different parts of the air; we muſt needs alſo obſerve many ſuch bright pillars or rays, which appear to interrupt the dark ſegment of the bright arch, and render it unformed, if they approach the matter thereof. Whence alſo is the appearance, as if theſe rays were ſhot upwards out of the dark ſegment and light arch: eſpecially when the kindling of ſuch a vapour-pillar happens quick, and from below upwards; as the undermoſt vapours thereof are longer, and more mixed with the air, than the upper. There is ſtill another manner poſſible, in which bright pillars may appear to the

eye.

eye. If at times the ſun ſhines through the rents of the clouds, but the reſt of the heavens overcaſt; theſe ſolar rays breaking forth out of the clouds become viſible to us, and appear like rods (§. 484). Now if we repreſent to ourſelves, that the kindled matter of the northern ſhine ſo eradiates in like manner through the rents of the matters, which form the dark ſegment, and enlightens the vapours, ſtrewed up and down in the air; it is eaſy to conceive, how in like manner bright rods may be produced all over the northern ſhine. The light rods produced in this manner M. *Mairan* calls *rays*; but thoſe produced in the manner above deſcribed, *pillars*: and is of opinion, that in a northern ſhine the rays have ariſen far oftener and in greatet plenty than the pillars. In a northern ſhine we may often ſee bright clouds, ſuddenly ariſing, and ſoon again diſappearing. They ariſe in the ſame manner as the pillars. The vapours, by their collection, need only form an irregular figure, and in falling down, be kindled, and the bright cloud appears. Some of thoſe clouds, in which the accenſion proves longſome, are of ſome duration: others, on the contrary, that admit a free accenſion, ſuddenly diſappear again. In the laſt caſe, there is an appearance as of lightening. If theſe flaſhes follow on each other in a regular manner in equal times almoſt; there ariſes the phænomenon, uſually called the *vibration of light*. From which ariſes the appearance of fiery waves ſeeming to roll up quite to the heavens;

namely;

namely, if the vibrations of light extend along the matter ſtrewed all over the heavens from the horizon up to the vertex. If we at times obſerve an uncommon quivering, or tremor, in the matter of the northern light; the cauſe thereof is to be aſcribed to the variable refraction, to which the rays of light are ſubject, ſo they paſs through the vaporous matter, ſtrewed up and down; juſt ſo as objects appear to us in a tremor, on viewing them through the vapour of a coal fire. The northern ſhine is, in its greateſt degree of intenſeneſs, when the pillars, mounting up from all ſides of the horizon, exhibit a crown near the vertex or zenith. The whole ſcene is a deception of the ſight. If we ſtand at the beginning of a long alley, its ſides appear to us to run pointed towards the end, though as broad at the end as at the beginning (§. 476). Now ſuppoſing, there were pillars of light ſet at certain diſtances aſunder quite round in our air, all of them placed upright on the ſurface of our horizon; we may conſider them as a number of ſuch alleys, which near the earth, or at the horizon appear to us widely expanded; on the contrary on high to run pointed towards the zenith, and there to exhibit a crown. The pillars are not always, in the manner abovementioned, perpendicular on the horizon, but placed from ſouth to north, as they participate of the diurnal motion of the air. And thus to the ſouth we look obliquely into theſe alleys or rows of pillars. And hence the crown appears to

us not juſt in the zenith, but ſomewhat more towards the ſouth. If now with the growing night the ſun conceals himſelf deeper under the horizon; the air above us has no further increaſe of vapours from the ſolar atmoſphere, now averted from us. Now as the vapours, already brought into our air, by virtue of the diurnal motion of the air, are even more impelled to the north; the northern ſhine muſt begin to turn ever weaker and weaker, to draw towards the north, and there at laſt to diſappear. Suppoſing there fell, at the going down of the ſun, the laſt vapours from the ſolar atmoſphere into our air; and which thus, during the twilight collected towards the north; at the end thereof we ſhould obſerve only a dark ſegment and bright arch and in the reſt, from a defect of the confluent matter, no more appearances would ariſe. But, at the going down of the ſun, ſhould ſtill ſome vapours fall down; perhaps a few pillars or bright clouds or the like, would come to view. Colours are peculiar to light (§. 219), and appear, on the refraction of a ray of light, and thereby on its being ſpli[t] or divided into different other rays, which then ma[y] produce in us the ſenſation of this or that other colour. And thus if we want to ſee into the poſſibility of colours in the caſe of a northern ſhine; w[e] need only conſider, that the inflamed matter of [the] northern light emits plentiful rays in all directions in like manner, that, during the northern ſhin[e] many yet uninflamed vapours are ſtrewed up an[d]

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down in our air, through which the mentioned rays of light paſs, are there refracted, and thus produce colours. Theſe coloured rays of light reach either directly to our eyes, and excite in us the ſenſation of the colour, which is peculiar to them; or they enlighten a quantity of ſtill uninflamed vapours, which then reflect this coloured light towards us, and thus appear coloured. The bright clouds of a northern ſhine, which often ſhew fiery, take in this laſt manner their riſe. Hither alſo belongs the phænomenon; viz. that at times the heavens appear all of a fire, and bring to our mind the thoughts of the fiery rain of the ancients; as one needs only repreſent to himſelf a reflection of the light, ariſing either from a great quantity of the denſe and uninflamed matter of the northern ſhine, or alſo from real clouds in our air.

CHAP. VII.

Of the Orbits, Nature, and Effects of Comets.

§. 628. THE appearance of the common motion of comets (§. 594.) ariſes from the diurnal motion of the earth about her axis (§. 596).

§. 629. In their proper motion they appear to proceed in their courſe under certain fixt ſtars (§. 594), and there, as it were, at the limits of the heavens, all the time of their being viſible, to deſcribe an arch of a circle. To determine, and delineate this apparent way, on an artificial celeſtial globe; we

we have the following procefs to make. We look into the heavens for two fixt ftars, between which the comet fo lies in a right line, that an extended ftring may cover it and the two ftars from the eye. At the fame time we mark with a ftring two other ftars, between which the comet in like manner lies in a right line. And then we feek for the two firft on the celeftial globe, and turn, and raife and deprefs it fo long, till both ftars ftand together in the horizon. The arch of this great circle, contained between thefe ftars, is marked with chalk or white lead. The two laft ftars in like manner are brought to the horizon, and the arch between them marked. The point, in which both arches mutually interfect, is the apparent place, which the comet had had at the time of the obfervation. On a following night four other fixt ftars are again fought out in the heavens, where ever between two of them the comet is feen in a right line. Thefe ftars we feek for on the celeftial globe, and bring as well the firft as the laft pair to the horizon, and mark the arch. The point, where they mutually interfect, is the apparent place, which the comet had had at the time of the fecond obfervation. Upon this we fo turn the celeftial globle anew, that the two places found of the comet fhall come to the horizon; and we mark as well the arch between both places, as alfo the great circle, which on the globe coincides with the horizon. And in this manner is difcovered the apparent way, in which we may fee the comet proceed

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under the fixt ſtars, ſo long as it continues to be viſible to us. If the way, the comet ſeems to take, is a great circle, we may at the ſame time obſerve on the celeſtial globe, where this way interſects the ecliptick and the celeſtial equator; and where thus the comet appears to paſs through both, when viewed from the earth. The apparent way of the comet, obſerved in 1744, was by the obſervations made at *Peterſburg*, and thoſe of Mr. profeſſor *Heinſius*, as follows: Inſtead of the old calendar or ſtile, which was uſed in the deſcription, I ſhall take the new. On *January* 16, the comet was for the firſt time obſerved at *Peterſburg* in the conſtellation of *Pegaſus*. About 5 ¾ in the evening it ſtood almoſt in a right line with the head A of *Andromeda*, and with *Algenib*, or the ſtar F, in *Pegaſus*, though it declined a very little to the eaſt from this line. It was alſo almoſt in the middle between both theſe ſtars, yet a little nearer F than A. From this it was judged, that the place of the comet in longitude might be in the 8th degree of *Aries*, with a northern latitude of 18 ½ degrees. On *January* 19, about ſeven in the evening, its longitude in the ecliptick referred to 6 ¾ degrees of *Aries*, with a north latitude of 18 ¾ degrees. On *January* 30, about ſix in the evening, the comet appeared in a right line with the ſtars F and D of *Pegaſus*, yet ſomething almoſt imperceptible to the weſt of this line. Its place in longitude was in 1 ½ degree of *Aries*, with a north latitude of 19 ½ degrees. On

February

February 4, about a quarter after eight in the evening, the place of the comet was in the 29th degree of *Pifces*, with a north latitude of 20 degrees. On *February* 18, a quarter after feven in the evening, the comet was to be feen near *Marcab* in *Pegafus*, or the ftar C. In regard to the ecliptick it appeared to the naked eye to be diftant to the fouth eaft from the faid ftar about a fourth of the moon's diameter; which was tolerably well to be judged of, as the moon was at the fame time in the heavens, and ftood not very far from the comet. And hence its longitude was 20 degrees of *Pifces*, but its north latitude 19 $\frac{1}{6}$ degrees. On *February* 20, towards feven in the evening, we could eftimate the place of the comet for the laft time; and as much as the bright twilight could permit, it was fuppofed to be in longitude about the 18th degree of *Pifces*, with a north latitude fomething over 18 degrees. At *Laufanne*, the comet was obferved the year before on *Dec.* 13. According to this, and the other obfervations made at *Paris*, Mr. profeffor *Euler* in his *Theoria motuum planetarum & cometarum*, p. 100. eftimates the longitude of the comet for *December* 13, at 28° 26′ 13″; for *January* 3, of the year 1744, at 14° 11′ 10′; for *January* 7, at 12° 3′ 10″ of *Aries*.

§. 630. That the way, in which we obferve a comet, is its true and real path, we are as little to conclude from obferving it among the fixt ftars, as to conclude that the fun runs along the zodiack, becaufe he there appears (597). And did comets

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describe circles in the region of the fixt stars; they, as little as the fixt stars, could appear at one time bigger than at another. The comet, whose apparent course we have been just now describing, appeared at *Petersburg* from *January* 16 to *January* 24, 1744, no bigger than the head of *Andromeda*, a star of the second magnitude. But on *January* 25, it looked bigger and brighter. On *January* 30, it shewed equal to a star of the first magnitude. On *February* 15, the body of the comet, through the *Gregorian* telescope, looked oval. The greater diameter was estimated as large, as $\frac{3}{4}$ of the diameter of the disk of *Saturn*. On *February* 18, it was rated at $\frac{4}{5}$. *February* 27, in the morning, the greater diameter, through the *Gregorian* telescope, looked as big, as to be rated at $\frac{2}{3}$ of the diameter of the disk of *Saturn*.

§. 631. We represent to ourselves the paths of the comets as very long ellipses, and we set one place, where they have the most curvity, very near the sun. The reason whereof is, because comets are visible to us only for a short time, viz. when they arrive in the regions lying near the sun; and after this become invisible again for a very long time, as they accomplish their course at a very wide distance from us and the sun. Of such an elliptical path but a small portion, which a comet at the time of its visibility describes, is known to us. It differs not altogether so remarkably from a very small portion of a parabola. And hence it is called the parabolick path. And it has been found sufficient to exp ain

the courſe of the comets in their apparent proximity. For, after having found out certain methods of calculating, from a few obſervations, the courſe of comets in ſuch parabola's; on comparing together the calculated places of a comet with thoſe afterwards obſerved, almoſt quite as accurate a coincidence has been perceived as in the caſe of the planets. And hereby a conviction aroſe, that the ways of ſeveral comets, though not their whole revolution through, yet ſo far forth as they paſs along in our neighbourhood, are determined with ſufficient certainty. This is the notion, communicated in general by Mr. profeſſor *Heinſius* in his mentioned deſcription of the paths of comets.

If one would form to himſelf a repreſentation on paper, how during the whole time, that a comet in its parabolick path has either approached to, or removed from the ſun, it muſt have appeared to the eye, as if it proceeded through the zodiack: this may be done as follows: you deſcribe round the ſun S, fig. 1. plate XII. the orbit of the earth, and round this, the zodiack. You mark in the earth's orbit the places, in which the earth has been for every day, at which the comet was obſerved in a determinate place of the heavens. Theſe places ſtand oppoſite to the places of the zodiack, in which the ſun had appeared to be. And thus if you draw from the apparent places of the ſun in the zodiack through the ſun to the earth's orbit right lines; theſe interſect the earth's orbit in the true places of the

the earth. In the zodiack we obſerve the degrees, to which the comet each day of obſervation is referred: from theſe degrees we draw right lines to the places, in which the earth in her orbit had been on thoſe very days, on which the comet in longitude was referred to the ſaid degrees. If one knows, how diſtant the comet might have been on a certain day from the ſun and earth; this diſtance, on the line, drawn for this day from the place of the earth to the place of the comet in longitude in the zodiack, gives the place of the comet in her parabolick path on this day. Now if from this place to the ſun we draw a parabolick line, which near the ſun is curve: and we carry it, on the other ſide thereof, on to the zodiack; the points, in which the lines drawn each day of obſervation from the true place of the earth in the zodiack to the obſerved longitude of the comet, are interſected, ſhew the places, into which the comet from time to time is come. And thus we may form to ourſelves the following repreſentation nearly of the path the comet of 1744 took. It lay between the ſun and that part of the earth's orbit, which the earth at the time of the comet's viſibility, had run over. On *January* 19, the comet was ſome little way more diſtant from the ſun, than the earth from the ſun. On *January* 19, the place of the comet in longitude was in the ſeventh degree of *Aries*; and the earth was in *e*, the ſun appearing to be in the 29th degree of *Capricorn*. And thus the comet may have been in its elliptical

or parabolical path in E. Describe round the sun for the curvity of the comet the curve line *n* P *o*, which on one side of the sun takes its way from *n* through E towards the zodiack, and on the other side proceeds from *o* in like manner towards the zodiack. And thus the comet was on *December* 13, 1743, in A; *January* 3, in B; *January* 7, in C; *January* 16, in D; *January* 19 in E; *January* 30, in F; *February* 4, in G; *February* 18, in H; and *February* 20, in I. For, on *December* 13, 1743, the earth was in *a*; *January* 3, in *b*; *January* 7, in *c*; *January* 16, in *d*; *January* 19, in *e*; *January* 30, in *f*; *February* 4, in *g*; *February* 18, in *h*, and *February* 20, in *i*; in regard the sun appeared to have his opposite place in the zodiack on *December* 13, in 22° of *Sagittarius*; *January* 3, in 13° of *Capricorn*; *January* 7, in 17°; *January* 16, in 26°; *January* 19, in 29° of *Capricorn*; and on *January* 30, in 11° of *Aquarius*, and on *February* 20, in 2° of *Pisces*. So that from the earth from *a* the comet must have been seen *December* 13, in the zodiack in 29° of *Aries*; *January* 3, from *b* in 15°; *January* 7, from *c* in 13°; *January* 16, from *d* in 8°; *January* 19, from *e* in 7°; *January* 30, from *f* in 2° of *Aries*; *February* 4, from *g* in 29° of *Pisces*; *February* 18, from *h* in 20°, and on *February* 20, from *i* in 18° of *Pisces*.

From this at the same time it is evident, why this comet all the time of its visibility must have appeared to us to be retrograde; whereas its true course was

was ſuch, that could we have been in the ſun, and obſerved it from thence, we ſhould have ſeen it direct. At the end of *February* it came to be in conjunction with the ſun, at which time it could not be ſeen on account of the ſun's ſplendor.

§. 632. The nearer comets come to the ſun, the more intenſely are they heated by his rays. The diſtance of the ſaid comet from the ſun amounted on *February* 29 to about $\frac{32}{100}$ of the mean diſtance of the ſun from the earth. And thus its diſtance from the ſun was to that of the earth from the ſun, as 1 to 3. Now the intenſeneſs of the light in a nearer diſtance to its denſity in a wider, is as the ſquare of the wider to the ſquare of the nearer diſtance (§. 146). And therefore the degree of heat, which the comet on *Februry* 29 had from the ſun, to the heat of the earth, was as 9 to 1. According to *Newton*, the heat of boiling water is about 3, and of glowing hot iron 9 times as great, as the heat, which a dry earth with us has from the ſun's heat in hot ſummer days. And thus the comet was on *February* 29 expoſed to ſo great a degree of heat, as that of a glowing hot iron. The comet of 1680 was in a 2000 times greater degree of heat. For, its diſtance from the ſun was to the diſtance of the earth from the ſame, as 6 to 1000. And conſeqently, the intenſeneſs of the action of the ſolar rays on the comet, to the intenſeneſs of their action on the earth, as 1000000 to 36, that is, as 28000 to 1. Suppoſing the heat of a glowing hot iron, to the

heat of boiling water, to be not as 9, but as 12 to 1; yet the heat of a glowing hot iron would be contained above 2000 times in that, which the comet had to abide. *Newton Principia*, lib. 3. prop. 41.

§. 633. It is asked, whether comets, on being exposed to so intense a degree of heat, become glowing hot? The time of their continuance therein appears to be too short for that purpose, considering too the magnitude of comets. A body gains its degree of heat, just in the manner it loses it. Now the times of cooling, in equally hot balls of one and the same matter, are to each other as their diameters, when in contact with one and the same, and an equally cold matter (§. 132). And so the time, in which a greater ball A is heated, to the time a less B heats of the same species in an equal degree of heat, will be as the diameter of the greater A, to the diameter of the less B. In the region, where a comet is, the sun's heat may be so intense, as that an iron ball an inch thick might become glowing hot in a minute. And thus a year would be requisite to make an iron ball, whose diameter amounted to 525600 inches, become glowing hot at this degree of proximity to the sun. For, so many minutes a year consists of. The comet of 1744 appeared oval, and its greater diameter contained 1376; and its least, 917 *German* miles. The mean number of which we will assume (§. 609), and thus represent to ourselves the comet as a ball, whose diameter is 1146 miles. Now consider we, that on

January

January 19, it was ſtill ſomewhat more diſtant from the ſun than the earth; and already at the end of *February* had begun to remove from the ſun; there is no reaſon why in this ſhort time it ſhould become glowing hot. Yet comets, that come ſo near the ſun, as came that of 1680, may perhaps become glowing, when they have a heat to abide 2000 times more intenſe than the heat of a glowing hot iron.

§. 634. But though we have no ſufficient grounds to hold comets for bodies ſuſceptible of being ſet on fire by the ſun; yet this we may maintain, that they are enlightened by him. For, the nearer they come to the ſun, the more intenſe their light; and on the contrary, the weaker, the farther they remove from him. And ſo the light of the comet of 1744, from the beginning of its appearance till *February* 21 become more intenſe. And, indeed, till the ſame time it alſo all along approached nearer to the earth. But though after *February* 21, it obſervably removed in a ſhort time from the earth; as its path was partly very curve, and partly the earth in her orbit followed it not ſo quick; yet however it ſtill gained ſome increaſe of light till *February* 29, as till then it ever approached ſtill nearer to the ſun.

That comets, either from their nature, or from an accenſion, otherwiſe cauſed, ſhould ſhine, can by no means be affirmed with any foundation. Only the greatneſs of their illumination cauſes ſome doubt in this reſpect. A comet, that by the theory ſhould appear enlightened but half, as a quarter moon, or

horned, appears with full light. Mr. professor *Heinsius* removes this doubt, as deriving the full shine of a comet from the illumination of its vapours, and from the refraction of the solar rays. The visible vapours, which the atmosphere of a comet consists of, spread through a wide space all around it; but are ever more condensed, the nearer they are to its body. The last is evident from the different degrees of the light. For, near the body, it is intensest, and ever decreases to the limits of the apparent atmosphere; as Mr. professor *Heinsius* represents this in his cited description on plate I. in the figure of *January* 5. On reckoning from the firm surface of the comet of 1744, the height of its apparent atmosphere was estimated at above 8000 *German* miles.

Suppose B D F, fig. 4. plate XI. to be the body of the comet, K E N to denote the outmost extent of its atmosphere, and I H G to separate a part thereof near the surface of the body or nucleus, where the vapours are most condensed. Further, suppose the line C A from the centre C of the body to be directed towards the sun, and C E towards the earth, and to stand perpendicular on A C. When the body of the comet, in the manner of the other planets, is enlightened by the sun, its half only D B Q is so. But from the earth the half B D P will be seen, just as the moon appears in her quarter; as only B D of the enlightened part thereof is turned to the earth. And yet the body of the comet

comet appears full. Now whence arifes this light? Suppofe O D to reprefent a ray of light, parallel with A C, in D touching the body of the comet, and in G illuminating a vapour, fo fituated as that P G falls parallel with C E. Under thefe circumftances it is clear, that the part R H G of the atmofphere I H G, enlightened by the fun, will produce the very fame effect in our eyes, as the half of the body B D P actually enlightened. We have allowed the ray O D G to pafs unrefracted through the atmofphere of the comet. No doubt, but that the rays of light in fo very large an atmofphere muft be very greatly refracted. And therefore the ray S K falling parallel with A C muft be propagated through the atmofphere in a curve line K L M; which confequently will meet with vapours, that partly lie much nearer the body as G, partly lie much more diftant behind in the part I H G of the atmofphere averted from the fun.

§. 635. The tail of a comet extends out of its atmofphere into the region of the heavens averted from the fun through a very wide fpace; and is enlightened by the folar rays, which force through the atmofphere. This tail, according to the different pofitions, it has to the earth, and the magnitude of the diftance therefrom, appears now longer, again fhorter. For inftance, fuppofe the earth in D, fig. 5. plate VII. and the comet in A, and its tail A B to form at A with the vifual line D A, in which the comet is feen, a right angle: fo that the length

length of the tail appears under the angle B D A. But if this equally long tail A C forms with the visual line D A at A an oblique angle; its length then appears under the angle C D A. Now as this is less than the angle B D A; the tail in the latter position appears less, and in the first, greater; though its length has remained unchanged, and neither greater nor less. But also the length of the tail itself may decrease and increase. In order from the apparent to find the true, the angle, under which the length appears, and the distance of the comet from the earth at the time of observation, must be known. And thus at *Petersburg* on *February* 4, 1744, the length of the comet's tail was observed under an angle of 26 degrees, and the true length found to be 7000000 miles.

§. 636. The tail of a comet arises from the vapours of its atmosphere, being driven away by the sun into the æther, the heat of the solar rays expanding or rarefying the comet's atmosphere. Here we have three queries to examine. As 1. Whence arise the vapours in the comet's atmosphere? 2. How the vapours therein can rise to so great a height, and be kept, as it were, floating therein? 3. How the rising of the vapours happens, and how from them the tail arises? A full answer to these queries Mr. professor *Heinsius* has communicated in his cited description, p. 61——103.

The vapours arise from the body of the comet. That they should derive from the solar atmosphere is improbable

improbable on this account; viz. as otherwiſe *Mercury* and *Venus*, which are conſtantly in the part, in which comets appear with their atmoſpheres, muſt have been encompaſſed with ſuch vapours. Further, we know of no other heavenly body, from which the vapours of comets might be derived. The more intenſely a comet is heated by the ſolar rays, the greater quantity of vapours appears on it. Whence it is evident, that the body of a comet evaporates. The comet of 1744 is an inſtance in point. On *January* 16, as it ſtill ſtood ſomewhat more diſtant from the ſun than the earth from the ſame, the light of its atmoſphere was very weak, and at a greater diſtance from the body ſtill weaker. On the contrary, on *February* 5, as the comet was only about $\frac{2}{3}$ ſo diſtant from the ſun, as the earth from the ſame, there appeared on the under limb of the body, obverted to the ſun, a peculiar bright vapour under the form of a beard. Theſe vapours gradually drew themſelves up more to the body, ſo as already on *February* 15 to have reached to half the body, and on *February* 27 to have occupied the whole body. From *February* 15 to 27, ſeveral layers or couches of vapours, diſtinguiſhed from each other by the intenſeneſs of the light, aroſe gradually from the body and followed upon each other.

The viſible atmoſphere of the comet of 1744 was above 8000 miles high. How is it poſſible that vapours can reach to ſo great a height, and there remain floating? In our atmoſphere watery exhalations

tions mount up and float, if ſo ſubtilized by the heat, as that, by virtue of the force of coheſion, they come into equilibrium with equally large particles of air (§. 136). Comets, that approach the ſun, have no want of heat (§. 632). Yet they muſt be furniſhed not only with a matter adapted for evaporation; but they muſt alſo admit the being reſolved into infinitely finer vapours than our water. The air, that lies next to the ſurface of a comet, enlightened by the ſun, is doubly heated; one time, immediately by the aſſailing ſolar rays; and another, by the heat the body of the comet in like manner acquires from the ſun. The air, bordering on the body of the comet, therefore, on the ſide, obverted to the ſun, is more violently heated and expanded, and conſequently lighter than the higher air. So that a motion ariſes; the air, nearer the body, and more expanded, and become lighter, paſſing through the denſer, and carrying along with it the vapours hanging therein. This air alſo puts that, through which it paſſes, into motion. The place of the air, firſt aſcending, is quickly ſupplied by other air, which partly by its own elaſticity, partly by the heat of the ſun and comet, is expanded. And thus there ariſes an inceſſant motion in the comet's atmoſphere, which, like a wind, proceeds towards that quarter, where it finds the leaſt reſiſtance. This motion is ever propagated to more diſtant regions. And in this manner, the ſtill more ſubtle vapours are carried off to ever remoter regions along with the ſtill more ſubtle air, in which

they continue to float. And hereby arise the above mentioned layers or couches of vapours; in regard the density of the air, and consequently of the vapours, at the less distances is greater; and at the greater, less.

The vapours of the comet's atmosphere were forced off out of it into the æther by the heat of the solar rays. And in this manner the form of a tail comes to appear, the ascending vapours being enlightened by the sun. Suppose *a b* fig. 5. plate XI. to be the body of the comet, and *d e f i* to represent its round atmosphere, and the line *c d* S to be directed towards the sun S, and *e c i* to stand perpendicular thereon. Draw *k l* and *m n* parallel with *e i*, and you have two sundry couches of air incumbent on each other, *e k l i* and *k m n l*; of which *e k l i* stands more distant from the sun than *k m n l*. If the sun acts with his heat on the next couch to him *k m n l*; the elastick force of the air will be throughout increased therein. So that each particle of air of this under couch will seek to expand itself towards the air particles of the immediately upper couch *e k l i*, and communicate thereto in a direction parallel with *c f* a continued motion, so the air in *e k l i* suffers not a too great resistance from that standing over it *o i*. But it falls away or ceases, if also the heat of the sun forces into this and into the still higher couch *o p*, and into all the other couches. And thus the degrees of elasticity are changed in all the couches In the undermost couch reigns the strongest; in the following it, a weaker degree.

For,

For, in the undermoſt the heat of the ſun acts the moſt intenſely. And thus the elaſticities decreaſe with the increaſing heights. So that the under couch is always capable of forcing into the next upper. Now if all theſe expanſions manifeſt themſelves at the ſame time, and towards the ſame point, as in the direction *c f*; on the ſcore of the quantity of theſe coinciding expanſions a very intenſe degree of motion muſt ariſe in the direction *c f*, whereby there mounts up a tail away from the ſun. In the comet of 1744 on *February* 4, the diſtance of its head to that of the extremity of its tail from the ſun was as 7 to 11. And conſequently the degree of heat at the head to that of the end of the tail, as the ſquare of 11 to the ſquare of 7, that is, as 121 to 49, or nearly as 5 to 2. For, the degree of intenſeneſs of the ſun's heat is proportioned to the denſity of the rays (§. 146). The ſun's heat at the head of the comet muſt therefore have gradually decreaſed about $\frac{3}{5}$ of its whole intenſeneſs through an extent of 7000000 miles quite through each couch, that at laſt at the end of the tail ſuch a ſmall degree of heat ſhould obtain, as was to the intenſeſt as 2 to 5. And thus on account of the equilibrium being deſtroyed at once in all the couches by the ſun's heat, there muſt ariſe in them at the ſame time a quick motion.

According to the explanation hitherto given, the vapours mount up on high in right lines, running parallel with the line *f c*. But experience ſhews, that the pillars of vapour riſe up in an oblique

lique direction, for inſtance *q x* and *y z*. Alſo the vapours collect at a conſiderable diſtance from the body of a comet towards the ſun; and then on both ſides mount up in a curve. The reaſon whereof is to be ſought for in the different denſities of the air in the comet's atmoſphere. The nearer the air of a comet is to its body, the denſer it is. In *s*, *q*, *r*, ſuppoſe there be three parts of air, that lie immediately on each other, are equally diſtant from the body, and conſequently equally denſe. They may, further, lie in three different couches, as *s* in the under, *q* in the middle, and *r* in the upper. And therefore the elaſtick force in *s* is intenſer than in *q*; and in *q*, than in *r*. And conſequently the air *q* may indeed expand from *q* to *r*, but not from *q* to *s*. Now further the air *q* in the line *e i* on both ſides is in like manner encompaſſed with air, as in *t* and *v*; with a denſer *t* to *a* towards the body, and with a rarer *v* towards *e*. As theſe air-portions lie in one and the ſame couch with the part *q*; they are, indeed, expoſed to a like degree of the ſun's heat, whereby their elaſticity is increaſed. But as the portion of air *q* is rarer than the portion of air *t*; and denſer than the portion of air *v*; the elaſtick force in *q* is weaker than in *t*; and intenſer than in *v*. So that the air cannot expand towards *t*, but perfectly well towards *v*. And therefore the air *q*, which, as was ſhewn a little before, has a tendency towards *r*, at the ſame time ſeeks a way for itſelf towards *v*. And thus moves between the lines *q r* and *q u* along the

the oblique line $q x$ (§. 13). From the like reasons the air in y on the other side of the body of the comet must mount up on high along the oblique line $y z$. In this manner one may easily see, why the visible atmosphere expands towards $m g$ and $n h$. The air, which in the under atmosphere towards the sun, for instance, in α, is nearer the body than the air between α and d, must by virtue of its greater density expand away from the body towards the sun. Yet this expansion is somewhat weakened; as the air lying towards d and nearer to the sun is somewhat more elastick. But now also the air α on both sides of the body of the comet a and b shocks against another air, equally dense therewith, but on the score of its greater distance from the sun less elastick. And consequently a part of the air α, which seeks to expand as well towards d, as laterally from a and b, by these conspiring forces (§. 13.) will take its course along $\alpha\ \beta$; and another part the direction along $\alpha\ \gamma$. The air in δ and ε, on account of its greater density, in which it exceeds the air in d, in like manner seeks to expand down towards d; and on account of its intenser elasticity, wherewith it exceeds the lateral air, to expand sideways. And thus by these conspiring forces it takes a middle course from δ along $\delta\ m$, and from ε along $\varepsilon\ n$. From these compound expansions arises a curvilinear motion, at first manifesting itself from the body away to the sun, but soon after swerving more and more from this direction, and on both sides the body

body mounting up on high. The elaſticity of the air in α is at the ſame time heightened by the heat of the body of the comet, communicated thereto by the ſun. And therefore the air expands farther from α downwards to *d*, before it breaks forth into the curvilinear motion on both ſides the body, than it would do, were its elaſticity increaſed barely by the immediate heat of the ſun.

The tail of a comet goes out of its atmoſphere far quicker than the ſtrongeſt wind in our air. The wind, by which in 1736 *September* 21, high water was cauſed in the ſtream of the *Nerva*, accompliſhed in the ſpace of a ſecond a way of 119 *Paris* feet. Had this wind continued its courſe with equal velocity, it would have made in a day 1713600 *Paris* toiſes, or 450 *German* miles, 15 of which conſiſt of 57060 toiſes. A wind is ever quicker, the more intenſe the elaſticity of the air, in which it ariſes; and the more the elaſticity of the yielding air decreaſes, and the farther this decreaſe extends in length. Now if we conſider the great degree of heat, which the comet of 1744 was expoſed to in the neighbourhood of the ſun (§. 632); how intenſely therefore muſt the elaſticity of its atmoſphere have been increaſed. Conſider only how inconſiderable the force may be, wherewith the ſubtle æther withſtands the mounting vapours. And thus, without any danger of doing violence to probability, we may appropriate a degree of velocity thereto, with which in a day it would have made 100000 miles. Mr. pro-

feſſor *Heinſius* in his deſcription, p. 45. ſhews, that the true length of the tail contained, in a hundred parts of the mean diſtance of the ſun from the earth on *January* 16, 14 ſuch parts, and on *February* 2, 35. So that in 17 days the tail was lengthened about 21 ſuch parts. A hundred parts make 22000 ſemidiameters of the earth, and conſequently 21 make 4620 ſuch parts. And thus on one day there were 271 for the length of the tail, which amount to 233060 *German* miles. But if the air proceeded with ſo aſtoniſhing a degree of velocity from the atmoſphere of the comet; it is to be wondered, that the comet was not in a ſhort time ſtript of all its air. Imagine at *g h*, fig. 5. plate XI. at the place, about which one may reckon the beginning of the tail, a ſection of the expanded atmoſphere, ſo that the plane of this ſection ſtands perpendicular on the line *f c* S, that paſſes through the comet to the ſun, and is bounded round like a circle, having for its diameter the line *g h*. We may very well reckon the length of this line, on account of the expanſion of the atmoſphere, which in itſelf is above 17000 *German* miles denſe, at 20000 miles. And thus the plane of the ſection will contain 314000000 ſquare miles. Now ſuppoſing the velocity of the iſſuing air ſo great, as in a day to make 100000 miles; in a day a cylinder of air would paſs through the plane of the ſection, whoſe baſe is the plane of the ſection itſelf, but the height 100000 miles, and conſequently its ſolid contents amounting to 31″400000′000000 cubick miles.

But the whole atmoſphere of the comet contained not ſo many cubick miles. How then could it conſiſt, that in all the time of its viſibility no obſervable decreaſe was perceived in it ? The air cloſe at the body is very denſe, and perhaps, on account of the high atmoſphere, charged with many vapours, denſer than the air on the earth's ſurface. This denſe air decreaſes with the height, and at length comes to be equal to the æther in rarity. Alſo no other air can iſſue out of the atmoſphere of a comet but that, which already has been as rare as the æther. For, a denſer cannot unite with the æther. Suppoſing, the whole ſpace from the ſun quite to *Saturn* were empty. If a cubick inch of air, as denſe as the air at the ſurface of our earth, was ſuffered to expand through it; yet this expanded air, according to *Newton*'s demonſtration, lib. 3. prop. 41. would retain a degree of denſity, which ſtill obtains in the atmoſphere of the earth at a height of 860 *German* miles, reckoning from the ſurface. This denſity is far greater than that of the æther, or of the air iſſuing out of the atmoſphere of the comet : for, its height amounts to above 8000 miles. From this it is evident, that the aſtoniſhing quantity of air, by which the atmoſphere of the comet daily decreaſed, would amount to a ſmall part of a cubick inch, if again brought together ſo cloſe or compreſſed, as to become as denſe, as the air at the ſurface of the earth. And ſo no alteration in the atmoſphere of the comet could have been

 obſervable,

obſervable, had even its denſe air near the body of the comet, all the time the comet was in the neighbourhood of the ſun, decreaſed about 100, or even 1000 cubick inches.

From this one may form a notion, how the tail of a comet may be ſo tender or ſubtle as even to tranſmit the light of the ſmalleſt fixt ſtar. Imagine a cubick inch, filled with vapours, ſo near together, as the particles of the air at the earth's ſurface; and let theſe vapours expand or diffuſe themſelves through many millions of cubick miles; it will be eaſy to conceive, how afterwards theſe vapours muſt part aſunder ſo wide, as to tranſmit the light of the ſmalleſt fixt ſtar without any remarkable loſs or diminution.

As the tail of a comet mounts out of its atmoſphere by the heat of the directly oppoſite ſun; it ſhould continue its courſe in the line, which may be drawn through the comet and the ſun. But it deviates from this line, and forms with it an oblique angle. And thus we ſay, it mounts up obliquely. The reaſon is; the vapours, ariſen out of the atmoſphere, are to be conſidered as a peculiar body, and different from the comet. But theſe vapours retain the centripetal and centrifugal forces, which, in the union with the atmoſphere, as part of the comet, they had had with it. For, by the aſcent they loſe not theſe forces. And thus if, for inſtance, the comet moves from D to H, fig. 2. plate XII. the vapours, ariſen out of its atmoſphere from D to L, are by their

their centrifugal and centripetal forces, juſt as the comet, impelled in a curve. But now the central forces of the vapours, ariſen from the comet in D to L, are not greater than the forces of the comet. if therefore the comet comes out of D to H; the vapours, which have ariſen from D to L, and are a different body from the comet, and in their paſſage have accompanied the comet, cannot be in O, as in the place, from which through the comet and ſun a right line may be drawn. For, had they reached the place O, they had accompliſhed a greater way, and had thus ran faſter than the comet. But is this poſſible, as they exceed him not in the intenſeneſs of the central forces? The like, in proportion, muſt happen to the other vapours, which, before the comet came to D, and after it had quitted the place D, had ariſen out of its atmoſphere. And hence the tail, inſtead of having, at the preſence of the comet in H, the right poſition H O, muſt extend itſelf in the oblique one H Q, as forming an oblique angle with the right line H O.

The vapours, which after the time, that the comet continues its courſe to H, are continually ariſing out of its atmoſphere, are quicker in the riſing or aſcent, than the vapour ariſen out of the place D; as the comet in its way from D to H approaches ever nearer the ſun. Theſe vapours, therefore, in all this time aſcended, to the time that the comet comes to H, are nearer the line H O, than the vapour, which aroſe out of the comet, when

in D. And hereby a tail, divided into ſundry branches, muſt come to view. And this will be moſt obſervable, when the comet ſtands neareſt the ſun.

And whereas the tail of a comet ſhould increaſe in its great approach to the ſun in apparent length, it is wont to decreaſe thereon. And ſo in 1744 from *February* 4 to *February* 8, the tail of the comet was become ſhorter about 2000000 miles. On *February* 8 it ſtill amounted to $\frac{28}{100}$ of the middle diſtance of the ſun from the earth; about *February* 20, to only $\frac{15}{100}$. And conſequently its length had decreaſed about three millions of miles. This apparent decurtation or ſhortening ariſes hence, that the vapours are the more ſtrongly diffuſed by the reſiſtance of the æther, the quicker they ariſe out the comet's atmoſphere by means of its elaſticity, heightened by the ſun's heat. For, the quicker, and conſequently the ſtronger a body impinges againſt an obſtacle, the more ſtrongly it reacts (§.8). If therefore the impinging matter diſſipates itſelf; it will be the more quickly diffuſed, the quicker its motion. And thus though the vapours, which riſe out of the atmoſphere of a comet that is very near the ſun, into the region or quarter of the tail, may reach juſt as great as, and ſtill a much greater height, than the vapours reached, when the comet was more diſtant from the ſun; yet on that account they cannot be viſible at this height, as they ſtand too diſtant aſunder. The great diſſipation ſets narrower

rower or ſhorter bounds only to their viſibility, but not to their aſcent. The diſſipation of the vapours is peculiarly promoted by the motion, with which they ſeek to accompany the comet in its path, which was deſcribed in the foregoing remark. For, this motion turns ever quicker, the more the comet approaches to the ſun. But the more this velocity increaſes, with the ſtronger reſiſtance the vapours are diſſipated by the æther, through which they are to take their way. And ſince the vapours accompany the comet in its motion; the vapours, ſucceeding each other, form a curved row. This curvity increaſes with the approach of the comet to the ſun; and the tail is parted into certain branches, or ſingle tails. And thus the following procure not that denſity to the foregoing which they otherwiſe give them, when following them almoſt in a right line.

§. 637. Comets are retained in their elliptick orbits round the ſun by their gravity towards him. For, gravity is the very ſame with the *vis centripeta* §, 17. 91). But where this is wanting, there can no motion ariſe about a point or centre (§. 100). But as the gravity of a comet, at its uncommonly great diſtance, is uncommonly weak; the queſtion is, whether ſo ſmall a degree of gravity be capable ſo to bend the courſe of the comet at the greater diſtance, as that the comet may again come back to the ſun? The more a comet removes from the ſun, the ſlower its motion. And therefore alſo by a ſmaller degree of gravity it may be drawn away

from the line, along which, by virtue of its centrifugal force, it ſeeks to remove from the ſun. The curvity of the path ariſes, when this line forms an angle with the line, along which it is impelled by the gravity towards the ſun. The greater this angle, the greater the curvity. And hence it is greateſt, when, for inſtance, in the neighbourhood of the ſun, the lines, along which both central forces act, form a right angle. If now a comet goes off from the ſun; at firſt the angle, contained between the ſaid lines, is very ſmall. So that there ariſes a very ſmall curvity. But as the gravity proceeds in its action towards the ſun, the comet will be every moment drawn ſomewhat from the line, in which the centrifugal force acts. So that the angle of both lines, and conſequently the curvity, turns gradually greater; as this may be explained from the doctrine of compound motions.

§. 638. In order to diſtinguiſh again a comet in its return, we muſt firſt make out by calculation, in what places it would be ſeen from the ſun; and ſecondly, review in the calculations, made in this manner, of comets formerly obſerved, whether they would have appeared in thoſe very places, when ſeen from the ſun. We conſider the ſun in this caſe as an immoveable point. So often therefore as a comet occupies one and the ſame place in its true and elliptick orbit, it muſt appear from the ſun under one and the ſame conſtellations. And conſequently from the laſt we may conclude to the firſt, and

and thereby know, whether a comet now appearing had been ſeen before. The places, from whoſe coincidence this appears, are principally the *perihelia*, and the points in which the ecliptick is interſected by the path of the comets. If in two comets, ſuppoſed to be obſerved from the ſun, we could diſtinguiſh, that they interſected the ecliptick in one and the ſame place, and had an equal degree of inclination, and that in their *perihelia* they were equally diſtant from the ſun, and that both *perihelia* ſtood in one and the ſame place of the heavens; we might with certainty conclude, that theſe comets differed not from each other. From the places, in which comets are obſerved from the earth, it cannot with certainty be known, whether and when a comet appearing had formerly taken its courſe round the ſun. For, a comet, formerly ſeen may in its reappearance be taken for another, when obſerved on the earth. For inſtance, on *January* 19, 1744, the comet was in its real path in E, fig. 1. plate XII. And at that time the earth had its place in its orbit in *e*. And from *e* the comet was ſeen in longitude in the 7° of *Aries*. Now ſuppoſing, that at the time, that the comet in its return occupied again the place E, the earth were in *a*; the comet would be obſerved in a quite different place in the zodiack. So that for the whole time of its viſibility, it would appear to take a quite different way, from what was obſerved in 1744. Two comets, that appear in different places, may on the earth be conſidered as one. For inſtance, let an elliptick orbit be carried round the

the ſun, which paſſes through the right line between the points *e* and E. Now if a comet comes, to which this path is proper, at the time, that the earth is in *e*, to a point, where theſe lines are interſected by the ſaid path; it would be ſeen on the earth along the line *e* E in the 7° of *Aries*, So that it would appear to be that very comet, which was viſible in 1744.

Mr. profeſſor *Euler*, in his *Theoria motuum planetarum & cometarum*, ſhews a method, how to determine the paths of the planets and comets from a number of obſervations, and explains it by a calculation of the true motions of the comets of 1680 and 1744. The time, in which the firſt accompliſhes its path, or in which it returns to its *perihelium*, amounts to 170 years. The path of the laſt differed little from a parabola. The time of its revolution may thus amount to ſome centuries. *Halley*, by a calculation from the obſervations extant has determined the paths of many comets, that had been obſerved for ſeveral centuries back. But there is none among them all, whoſe path agreed with the paths of the comets of 1680 and 1744. From this however, no objection can be drawn againſt *Euler*'s calculation. For, as at the time, in which a comet is in the neighbourhood of the ſun, the earth may have ſuch a poſition in her orbit, as that there the comet muſt remain inviſible to the eyes of men; and ſo both the ſaid comets may be of the number of thoſe, which for all the time, of which we have obſervations of comets accurately made, and tranſmitted by writing,

ting, had not been ſeen. And if the comet of 1680 finiſhes his period in 170, it will in 1850 come again in vicinity to the ſun. But ſhould it then reappear to *Europeans*, the earth, as well in reſpect to the comet, as alſo to the conſtellations, under which it was ſeen in 1680, muſt again have that poſition, which ſhe had at the time of its former viſibility. So that it is to be made out by calculation, whether in 1850, or the year following, the earth might have this poſition.

§. 639. The comets that move round the ſun, are parts of the ſolar and planetary ſyſtem; and conſequently alſo gravitate towards the planets. And thus planets and comets, that have their revolution round the ſun, act reciprocally on each other. This action is clear from thoſe very grounds, from which (§. 624.) the actions of the planets on each other were made out. The nearer that two bodies, which by gravity act reciprocally on each other, mutually approach, the more intenſely they act on each other. Should therefore a comet come very near the earth; it might well happen, that the plane of its orbit would be in ſome meaſure changed. In particular this change muſt be conſiderable, when the comet is not only very near the earth, but has alſo a great degree of latitude (§. 558). For, the greater that is, the leſs can the ſun, by its gravity or attractive force, act on the comet, and conſequently the leſs weaken its action on the earth. The action on the earth may be perceivable in two ways; either in the obliquity of the ecliptick, or in the

the motion of the equinoctial points. Mr. professor *Euler*, in his *Theoria motuum planetarum & cometarum*, p. 99. speaks of both these changes, as follows. If a comet very near the earth should have a north latitude, and the sun stand in *Aries*, the obliquity of the ecliptick would be increased. But if in *Libra*; the obliquity of the ecliptick would be diminished. If the sun should be in *Cancer*; the equinoctial points would be moved forwards. Whereas if he stood in *Capricorn*; they would be pushed backwards. But if the comet has a south latitude; these changes come to be the reverse. And hereby the recession of the equinoctial points, which is caused by the actions of the sun and moon (§. 622.), must thus undergo a great change. The obliquity of the ecliptick has been considerably diminished from the most early times. M. *Euler* thence makes the conclusion, that many comets, either with a north latitude, when the sun had its place in the northern signs; or with a south latitude, when the sun was in the southern signs, might have approached to the earth, and have caused the said diminution. As the comet of 1744, fig. 1. plate XII. was in the descending node, his heliocentrick longitude, or that observed from the sun, was in the 15° of *Scorpio*, and *Mercury* in the 26° of the same. So that both these bodies were very near each other. M. *Euler* therefore p. 135 accounts it worth the while to enquire, whether *Mercury*, in his motion, still agrees or no, with the astronomical tables; and thus has undergone a change in his orbit. In particular, to him

him the laſt appears poſſible, when the apparent diameter of the comet at the time, that its diſtance from us was equal to the diſtance of the ſun, amounted to 1′, and thus its body exceeded the earth in magnitude above three times.

As a comet, by its attractive force, may diſturb a planet in its orbit, ſo a planet, by its re-action, may cauſe a like change in that of a comet; eſpecially if the planet be bigger than the approaching comet.

Should a planet be touched by a tail of a comet, or plunge into its fluid matter, therefrom a change would enſue in its atmoſphere, juſt as well as from the vapours of the ſolar atmoſphere (§. 627). And though the vapours of a comet's tail are uncommonly rare, yet we are not to leave their great velocity unregarded (§. 636). For the greater the velocity, the more intenſe the action of a moving and impinging matter (§. 37). For all the time, that in 1743 and 1744 the comet was viſible in *Europe*, the mercury ſtood uncommonly high in the barometer at *Peterſburg*. Mr. profeſſor *Heinſius*, in his deſcription of this comet, p. 21. ſet down the heights of the barometer in a table. Should, ſays he on this occaſion, this phænomenon happen to have been obſerved in like manner at other places, and been univerſal; it would be abſolutely a remarkable circumſtance; as whether from it no connection with a comet might be ſeen. Should, in his opinion, on a future appearance of a comet, the very ſame thing be obſerved in the heights of the quickſilver in the barometer; theſe uncommon circumſtances

cumſtances would yield no ſmall ſign, that the terreſtrial atmoſphere underwent a change by the matter of a comet; eſpecially, if the viſible tail mixed itſelf therewith.

CHAP. VIII.

Of the Action of the Æther on the Planets in their Motions.

§. 640. AS the æther is a fluid matter, in which the planets float: we are to enquire, whether they are not in ſome meaſure reſtrained by it in their motions round the ſun? If the æther moves at the ſame time with them and with equal velocity round the ſun, it gives them no manner of reſiſtance. But the æther has no ſuch quick motion. For, if it moved equally quick with them, it would hurry along with it the tail of a comet, and thus quite turn it off from the way, in which it mounts off from the ſun. But this in no wiſe happens. And thus we have ground to maintain, that the planets from time to time meet with ſome degree of reſiſtance in the æther, in continuing their courſe through it. But how great that reſiſtance, cannot be determined with certainty: as we know not ſufficiently, what ratio the denſity of the æther may have to the denſity of our atmoſphere.

Mr. profeſſor *Euler*, in his *Nova theoria lucis & colorum*, §. 36, 44—50. compares the velocity of light, propagated through the æther, with the velocity of ſound, propagated through the earth's atmoſphere;

mosphere; and thence shews, that the æther is 400′000000 times rarer than the earth's atmosphere. In his dissertation *De relaxatione motus planetarum*, §. 5, 6. he enquires what quantity of space the earth in this so rare an æther may have to run over, till it have lost $\frac{1}{1000}$ particle of its velocity. And this space would be to the semidiameter of the earth almost as 100000′000000 to 1.

§. 641. If the velocity of the planets is diminished by the resistance of the æther, they come nearer to the sun by their centripetal force or gravity. For, by so much as their velocity diminishes, and consequently their centrifugal force is weakened, by so much stronger is the gravity, as which in this case undergoes no diminution. But so the gravity act stronger; the motion in the now narrower way will be quicker, and thus the revolution round the sun finished in a shorter time. A planet, in its greater distance from the sun is restrained by the resistance of the æther, so as not to be able to finish in an equal time again its greater way, which it had before finished in a certain time. But this very thing also befals it in the now less distance from the sun; as in the shorter way the æther in like manner withstands it. And consequently by its gravity it will be again brought nearer the sun. And thus, as well its distance from the sun, as also its periodical time, or the time, in which it once accomplishes its way round the sun, constantly diminishes. And therefore should the constantly decreasing *vis centrifuga* of the planets be again not redressed; they

must

muſt at length pitch on the ſun's ſurface. In this manner the planetary ſyſtem would ceaſe to be, and the body of the ſun be increaſed with new matter, and thereby changed and enlarged.

The *Julian* year contains 365 days and ſix hours. The tropical year, or the time which paſſes from one equinox, or ſolſtice, to the ſame again, is at this day eſtimated at 365 days, five hours, 48′ 55″. It is not known, that the aſtronomers of the earlieſt ages had remarked this difference, whereby the tropical year is leſs than the *Julian.* From this it is to be conjectured, that at that time the length of the tropical year came nearer to the length of the *Julian* than now it does. In the immediately preceding centuries the duration of the tropical year was deemed greater than 365 days five hours 49′. Mr. profeſſor *Euler* from thence concludes §. 23. *de relaxatione motus planetarum*, that perhaps one would not greatly fall ſhort of the truth did he ſuppoſe, the periodical time of the earth to have diminiſhed each century about five ſeconds.

And then §. 24. he enquires, how far with this ſuppoſed decreaſe of the periodical time of the earth in a century the above adduced conjecture is conſiſtent, according to which, the ſpace, in which the revolving earth muſt loſe $\frac{1}{1000}$ particle of its velocity, ſhould be to the earth's ſemidiameter, as 100000′000000 to 1. As the perodical time of the earth in a thouſand years is about 50″ ſhorter; Mr. *Euler* reckons for the decreaſe of the periodical time in a thouſand years, in the caſe of *Saturn*, 33″; of *Jupiter*,

piter, 15″; of *Mars*, 62″; of *Venus*, 25″; and of *Mercury*, 33″. The excentricity (§. 609.) in like manner decreaſes. But M. *Euler* ſets this decreaſe in 2720 centuries only at a ſingle ſecond. As the paths of the comets are very excentrical; he holds §. 26. that their periodical times in each revolution might be conſiderably ſhortened; and thence he is of opinion, that it is no wonder, that the comet, which appeared in 1682 returned at firſt after 76, but after that in 75 years to its *perihelion*. For, it is held for that comet, which was obſerved in 1531 and 1607.

CHAP. IX.

What the ÆTHER may contribute to the firmneſs of BODIES.

§. 642. A Copper wire, $\frac{1}{10}$ of a *Rhinland* inch in thickneſs, is ſo firm, as that 299lb. muſt be hung at it, in order to ſnap it in ſunder (§. 57). The bare preſſure of the air againſt the ſurface of this wire is not much greater than the preſſure of 2 $\frac{1}{2}$ ounces weight. So that, beſides the air, there muſt be a matter, that preſſes far more intenſely againſt bodies, and thereby cauſes their firmneſs, than the atmoſphere does.

The calculating the preſſure of 2 $\frac{1}{2}$ ounces of air againſt a circular ſurface, whoſe diameter is $\frac{1}{15}$ of a *Rhinland* inch, depends on the following particulars. Againſt a circular ſurface, whoſe diameter is a *Paris* foot, the air preſſes with a force of 1703 $\frac{1}{2}$ lb. or 3407 half pounds. The

Paris foot is to the *Rhinland*, as 1440 to $1391\frac{8}{10}$. The preſſure of the air againſt a greater circular ſurface is to the preſſure againſt a leſs, as the ſquare of the diameter of the greater circle to the ſquare of the diameter of the leſs (§. 120). And thus $1440^2 : 1391^2 :: 3407 : 3179$. And if 3179 half pounds are reduced to whole pounds, and theſe multiplied by 32 loths or half ounces; the preſſure of the air againſt a circular ſurface, whoſe diameter is a *Rhinland* foot, is equal to 50864 loths or half ounces. A foot is = 100 lines. So that the preſſure of the air againſt a circular ſurface, whoſe diameter is $\frac{1}{100}$ particle of a *Rhinland* foot, that is, $\frac{1}{10}$ of an inch, is not much greater than the preſſure of a 5 loth or $2\frac{1}{2}$ ounces weight. For, $100^2 : 1^2 :: 50864 : 5\frac{864}{10000}$.

§. 643. From the explication of the propagated motion of light, it is evident, that it is elaſtick (§. 210, 211). Could we therefore prove, that, beſides the air, light or æther is the alone moſt ſubtle matter, that acted with a certain degree of elaſticity; we might conſider the æther as the ſtrongeſt cauſe of firmneſs; and maintain, that its elaſticity, to the elaſticity of the air, was as 1912 to 1. For, the cauſes of the firmneſs act againſt the ſurface of a copper wire, in diameter $\frac{1}{10}$ of a *Rhinland* inch, with a preſſure of 299 pounds, or 9568 loths. The preſſure of the air, as the weakeſt cauſe of firmneſs, is equal to five loths. And thus there remain, for the preſſure of the ſtrongeſt cauſe, 9563 loths. But 9563 is to 5, as 1912 is to 1.

CHAP.

CHAP. X.

Whether the Motions of the Sun and Planets about their Axis may be explained from their mutual Gravity towards each other?

§. 644. SUPPOSE the ſun to be in T, fig. 4. plate x. and a planet in L in ſuch a manner, as that the line L T paſſes through the centres of the planet and ſun. Let L C repreſent the arch, which the planet, by its central forces, may deſcribe in an inſtant; C the point, in which, at the end of this inſtant, its centre would be, ſo it deſcribed the ſaid arch. Now did the planet at this inſtant loſe its centripetal force; its centre would reach therein to B (§. 617). In this point B its centre would be more diſtant from the centre of the ſun T than the end of its diameter towards L. But the centre of the planet, in the inſtant, in which by the centrifugal force alone it would reach the point B, comes into the point C, which is in the circumference. The reaſon whereof is, its gravity towards the ſun (§. 617.) Now if in the time, in which it might be in B, it comes to C; it is juſt all one, as if the planet had acquired a degree of winding or turning, and conſequently a beginning towards motion about the axis. What gravity produces in the one inſtant, that it effects in all the following inſtants. And thus the planet will be gradually turned thereby about its axis.

§. 645. The ſun acts by its gravity towards the planets. Now as theſe in their orbits ever occupy

different places; so thus the sun has from one instant to another a tendency, to approach the planets ever towards different points (§. 619, 620.) Next, consider we, that even the centrifugal force, which seeks to impel the planets in a right line, acts in like manner on the sun, and his motion about the axis or centre may be considered as a motion, arising from two conspiring forces, as of his gravity towards the planets, and of the *vis centrifuga* acting thereon. In like manner, from the gravity of a planet towards its satellites, and from the gravity of a satellite towards its primary planet, their motions about their axes may be explained.

That two easily moveable balls revolve about their axes, when acting on each other by a fluid matter, may be explained by electricity. If of two bodies, both of them suspended at threads and easily moveable, one be electrified; they move towards each other (§. 251). For, the electrical matter of that electrified is by the electrification dissipated and diffused into a wider space, and tends to hurry along with it its body towards the unelectrified. So soon as the electrical matter of the electrified body is dissipated and rarefied; the electrical matter of the unelectrified forces into the rarefied space, which is round the electrified body. For, the electrical matter of the unelectrified is not only elastick, as the electrical matter of the electrified body, but also denser. Now as in the rarefied space round the electrified body it meets with a weak degree of resistance, it will be thus by its greater elasticity expanded

panded and diſſipated. So that in like manner it alſo tends to hurry along with it its body towards the electrified. And thus both bodies approach each other, as two bodies, reciprocally acting againſt each other by gravity. Did the gravity of the ſun towards a planet,and of a planet towards the ſun, ariſe by this means; viz. that ſun and planet were filled and encompaſſed with an elaſtick matter; which, in the manner of the electrical matter acted from the ſun upon the planet, and from the planet upon the ſun; we might ſhew by an example, that two eaſily moveable balls, by the action of their gravity on each other, moved about their axes The balls, that were uſed for the purpoſe, were hollow, and made of gypſum or plaſter-ſtone, and done over externally and internally with paper. In the cavity is a metal croſs, whoſe middle has a coniform excavation, in which the balls reſt on pointed metal pins. One point *a b*, fig. 3. plate XII. gives thro' a glaſs tube *c d* reſting on a ſmall foot *e f*, and cemented therein with ſealing wax. On the glaſs tube above a narrow plate *g h* of metal is faſtened, and at *i* a metal pin *i k* lodged. On theſe pointed pins the balls *k* and *l* reſt, and ſtand ſo diſtant aſunder, as that their electrical matters may act on each other. Round the pin *a b* a metal chain is laid. So ſoon as the electricity is given to this chain; the ball *k* will be alſo electrified. The ball *k* retains the communicated electricity for ſome time; as the pin, on which it reſts, lodges in a glaſs tube. And that the ball *l* may not acquire and retain a like electricity

electricity from the near ball *k*; as the plate, on which its pin has its ſtand, is faſtened on the glaſs tube *c d*; there is at *i* a metal chain laid, which reaches quite to the bottom of the foot. Now if the ball *k* is electrified, both it, and alſo the ball *l* come into motion, whereby they turn about their axes; and ceaſe not turning, ſo long as the ball *k* is ever acquiring new electricity. The rotation of theſe balls ariſes by this means; viz. that the electrical matter of the ball *k* goes towards the ball *l*, and the electrical matter of the ball *l* towards the ball *k*. And thus each ball, by the impulſe of the expanding electrical matter of either, is brought into motion about its axis. By ſuch like motions, to the knowledge of which I attained in 1746, by a variety of experiments in the courſe of electrifying, I attempted in 1747 to imitate the motion of the ſun about his axis; and as well the diurnal motion of the earth about her axis, as alſo her annual motion round the ſun, and I explained the machine, executed for the purpoſe in 1750, in a *Programma de imagine motuum cœleſtium, viribus electricis efficta*, and exhibited it on a copper-plate.

CHAP. XI.

Of the Connection of the fixt STARS with the Solar and Planetary Syſtem.

§. 646. WHETHER the fixt ſtars ſtand in connection with the ſun and his planets, from the fixt ſtars gravitating towards the ſun

ſun and his planets, and the ſun and planets towards the fixt ſtars, is what hitherto can neither be affirmed nor denied; as no phænomena in the heavenly bodies are known to us, that could give any indication thereof. And alſo did the gravity of the fixt ſtars extend to the planetary ſyſtem, and the gravity of the ſun and planets to the fixt ſtars; yet it would be uncommonly ſmall, as the diſtance of the fixt ſtars is uncommonly great. Suppoſe A D, fig. 4. plate XII. to repreſent the ſemidiameter of the earth's orbit, and the earth to be therein in A, and *Sirius* in R. The annual parallax is ſo ſmall, as that it cannot once be rated at two ſeconds of the circle. Suppoſe then the parallactick angle A R D (§. 611.) to be about one ſecond: therefore A D is to A R, as the ſine of a ſecond is to the ſine total; and conſequently, by *Pitiſcus*'s canon, as 48481 to 10000000000, that is, as 1 to 206262 nearly. Now A D, the diſtance of the earth from the ſun, amounts to 22000 ſemidiameters of the earth (§. 612). And thus, by the rule of three, A R is 4537′764000 ſemidiameters of the earth. So diſtant would *Sirius* be from the earth. Did a ſpectator in *Sirius* turn his eye to our ſolar and planetary ſyſtem, he would from there ſee nothing but the ſun under the form of a luminous point; as M. *Haupt*, formerly profeſſor of mathematicks in the electoral ſchool at *Grimme*, ſhews in his *Inſtitutiones Aſtronomiæ ſphæricæ, Theoricæ & Comparativæ*, §. 616. And therefore from our obſerving no planets about the fixt ſtars, we are not to conclude that none move round the fixt ſtars.

On

On the contrary, with Mr. profeſſor *Segner* in his introduction to natural philoſophy, §. 669, from the fixt ſtars, notwithſtanding their great diſtance, being diſtinguiſhable on the earth, we may conclude that they yield not to the ſun in magnitude.

§. 647. But how long or diſtant ſoever this way is, yet they act with their light quite to the earth, without being hindered in its paſſage by the planetary and ſolar light, which in the night enlightens the planets. But the action of the light of the fixt ſtars takes up a far longer ſpace of time in its courſe to the earth, than the action of the light of the ſun. For, the diſtance of the ſun from the earth is to the diſtance of the fixt ſtars from the ſame, as 1 to 200000 (§. 646). Now the ſun's light takes eight minutes, in coming to the earth from the ſun (§. 207). For the light of a fixt ſtar therefore to propagate its action as far as to the earth; 1'600000 minutes, or above 1111 days are neceſſary. Were another fixt ſtar ten times as diſtant from the earth; 16'000000 minutes, and conſequently 30 years and above would paſs, before the motion of the light from this fixt ſtar, or its image could reach our eye. Mr. profeſſor *Segner* ſays in the place quoted, §. 668; this is nearly the magnitude of that part of the world, that affects our eyes. And perhaps this part, in regard to the whole, is ſomething very inconſiderable. And thus the Creator how great, and we how little!

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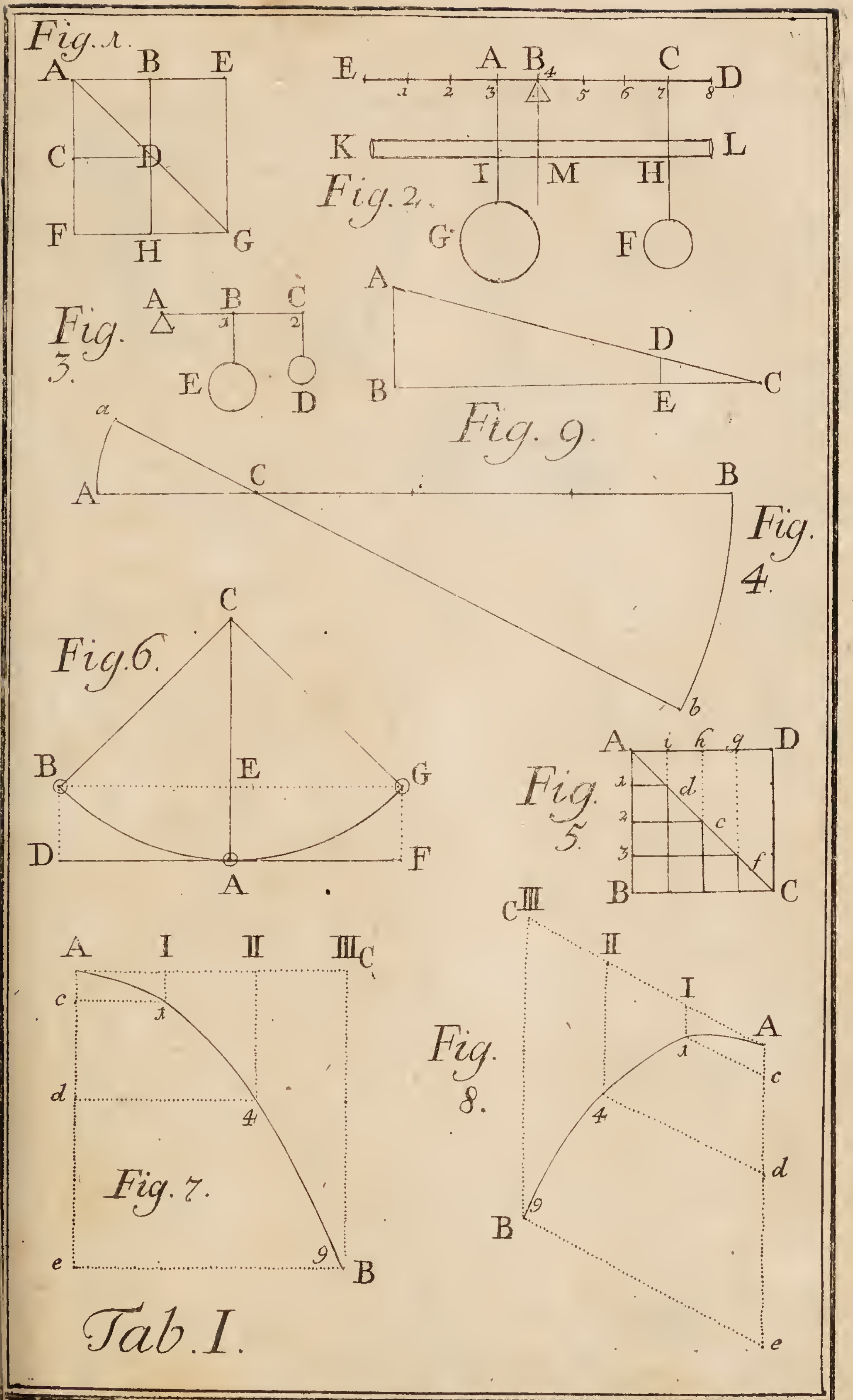
Fig. 1.
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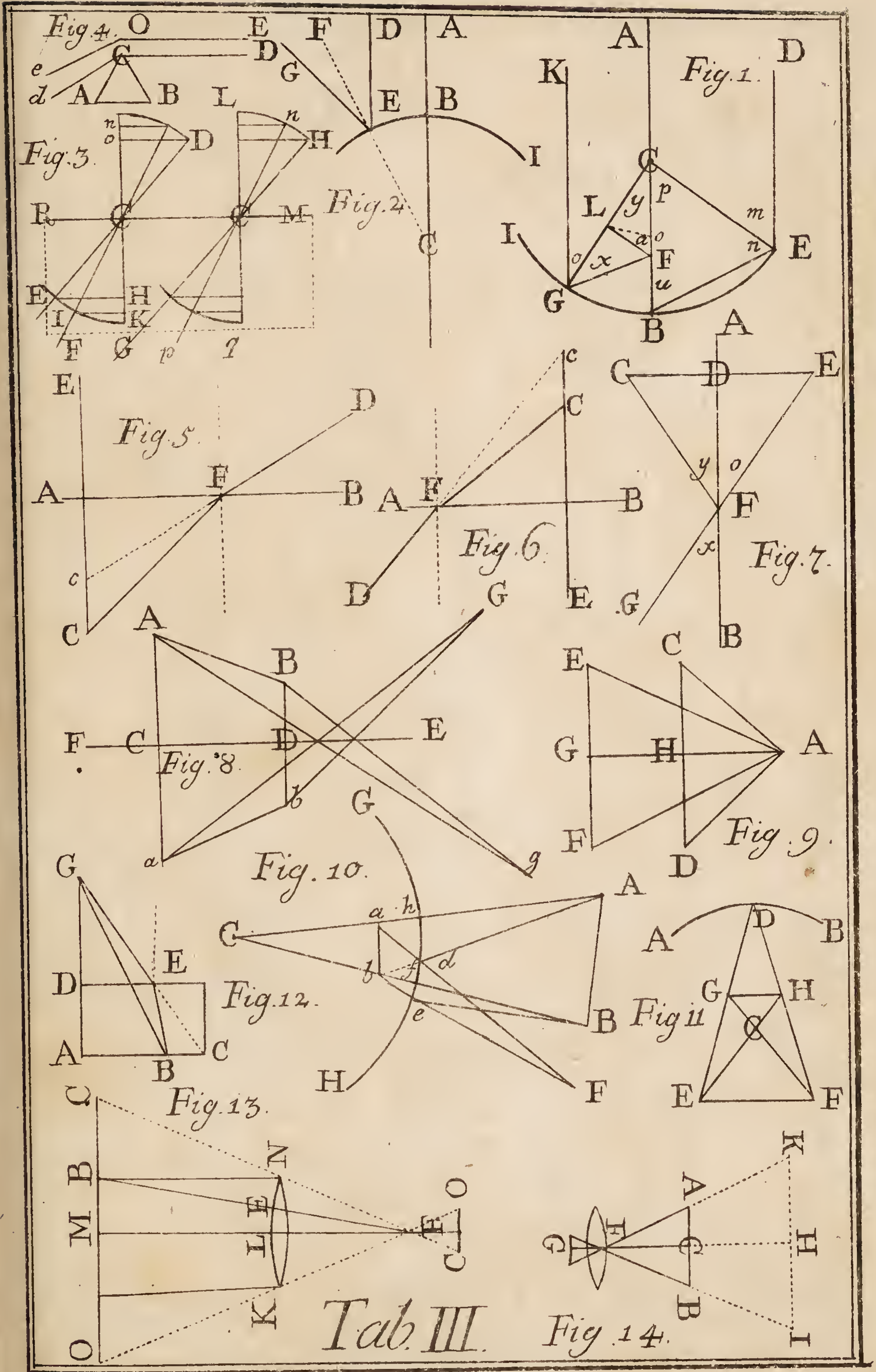
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Tab. III.

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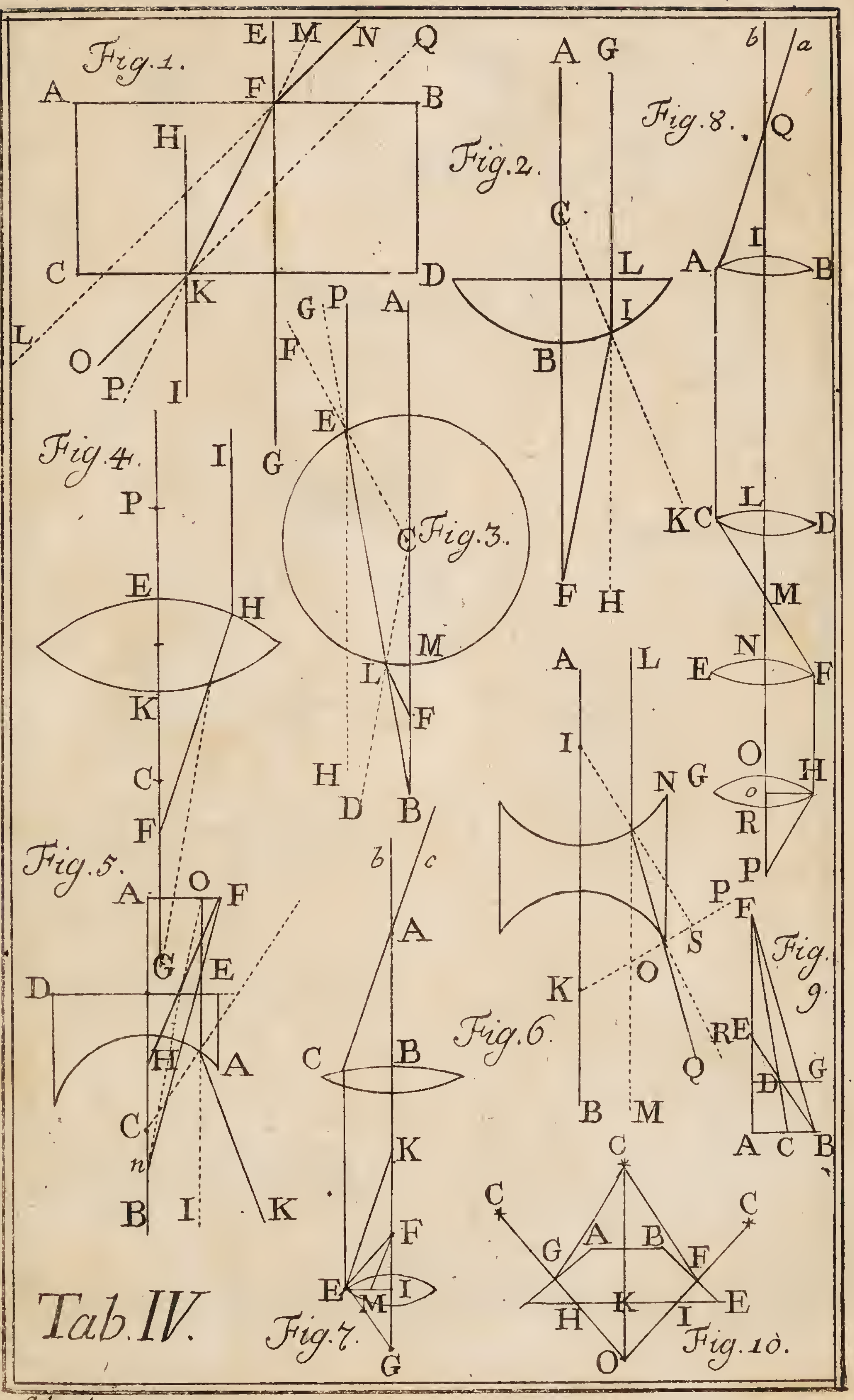

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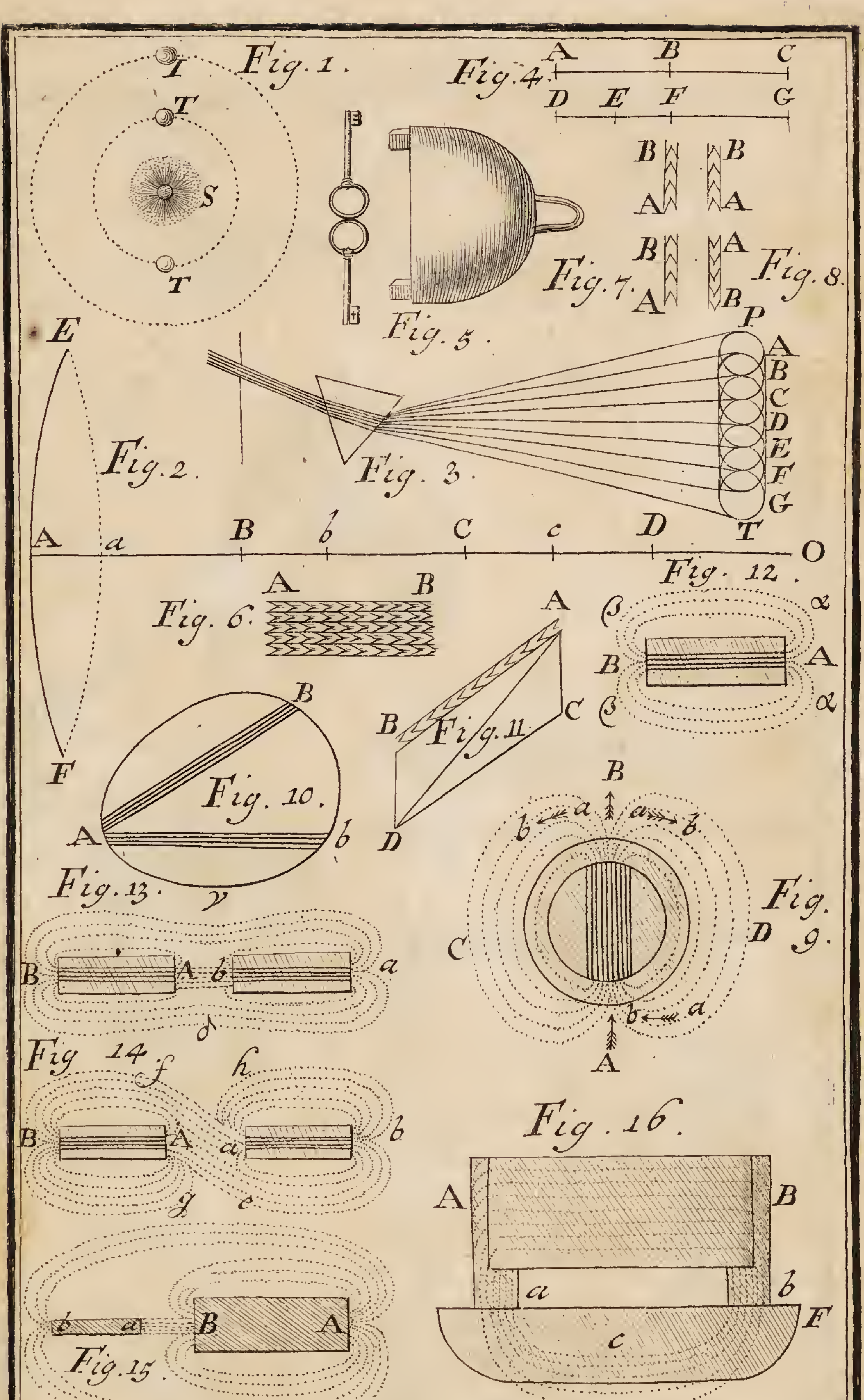

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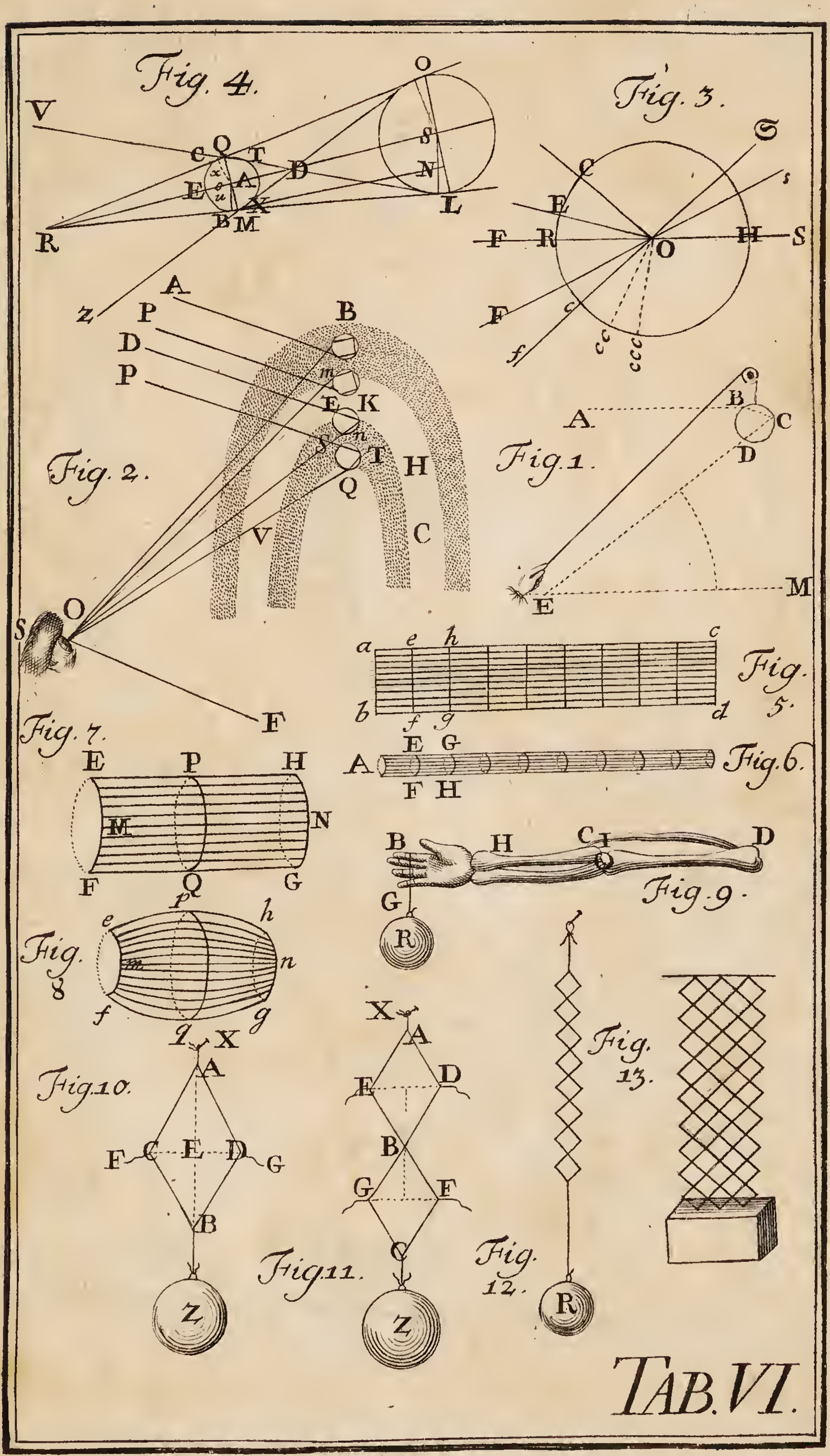
TAB. V.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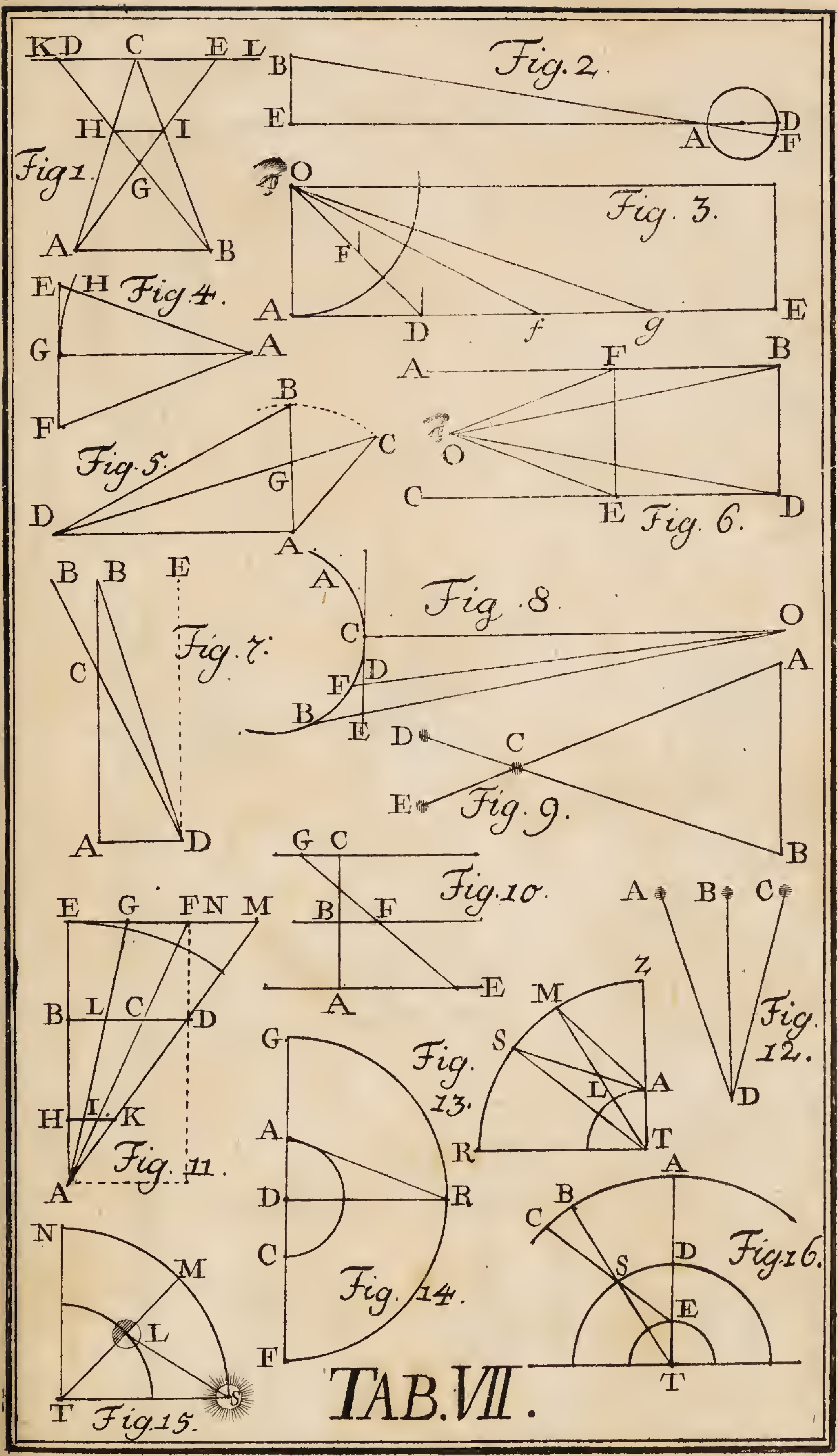
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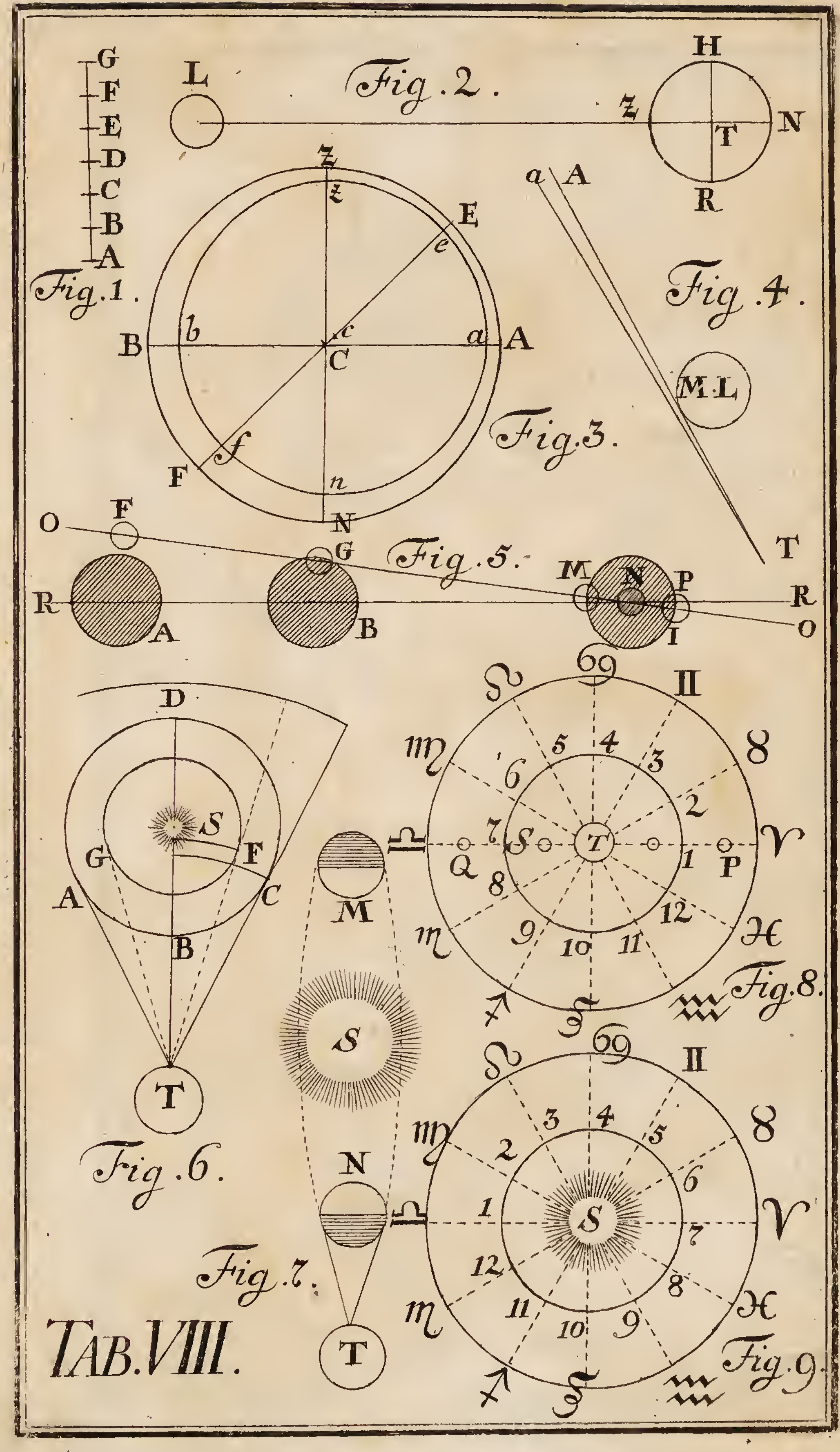
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O F G M N P R A B I
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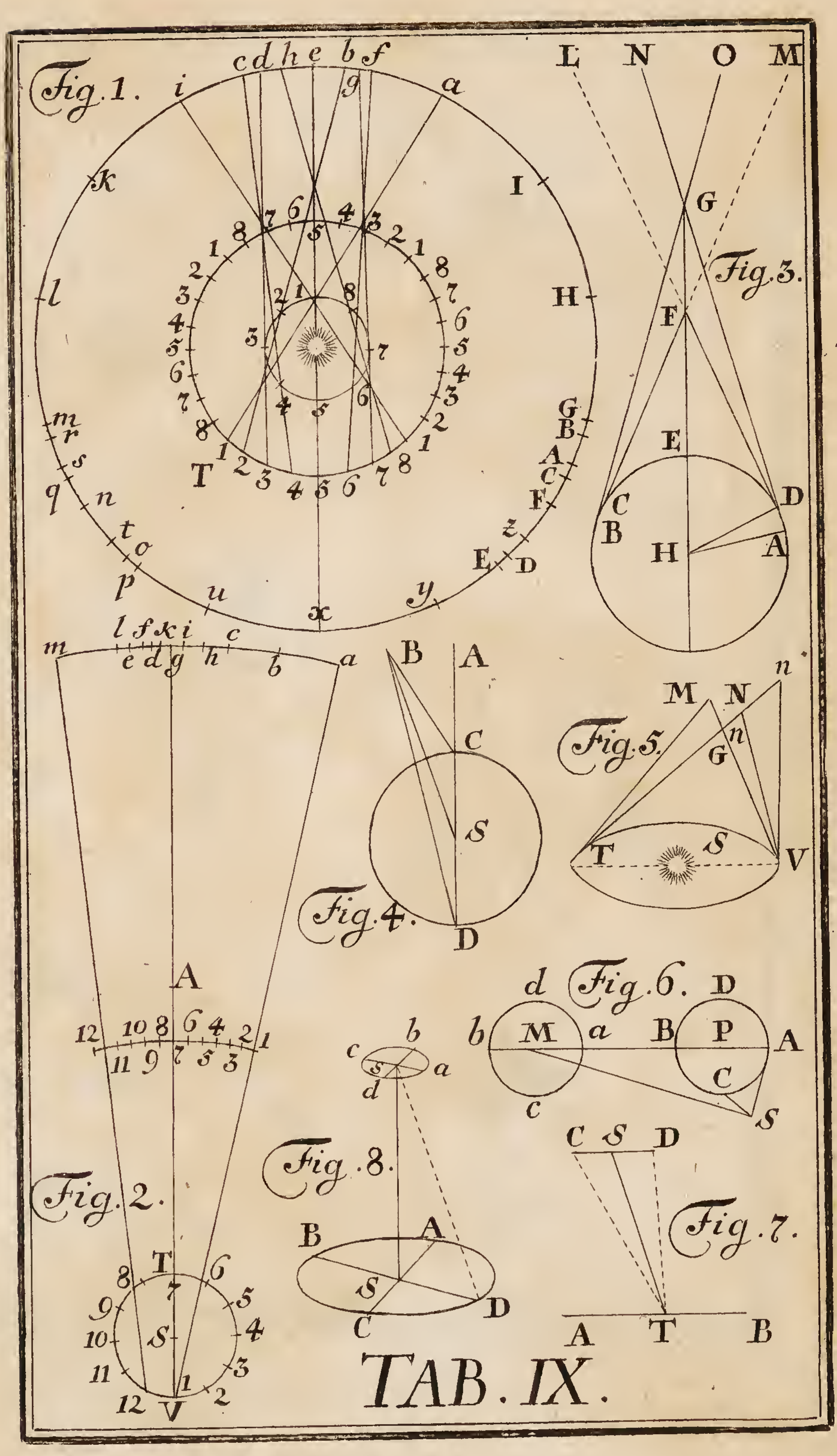

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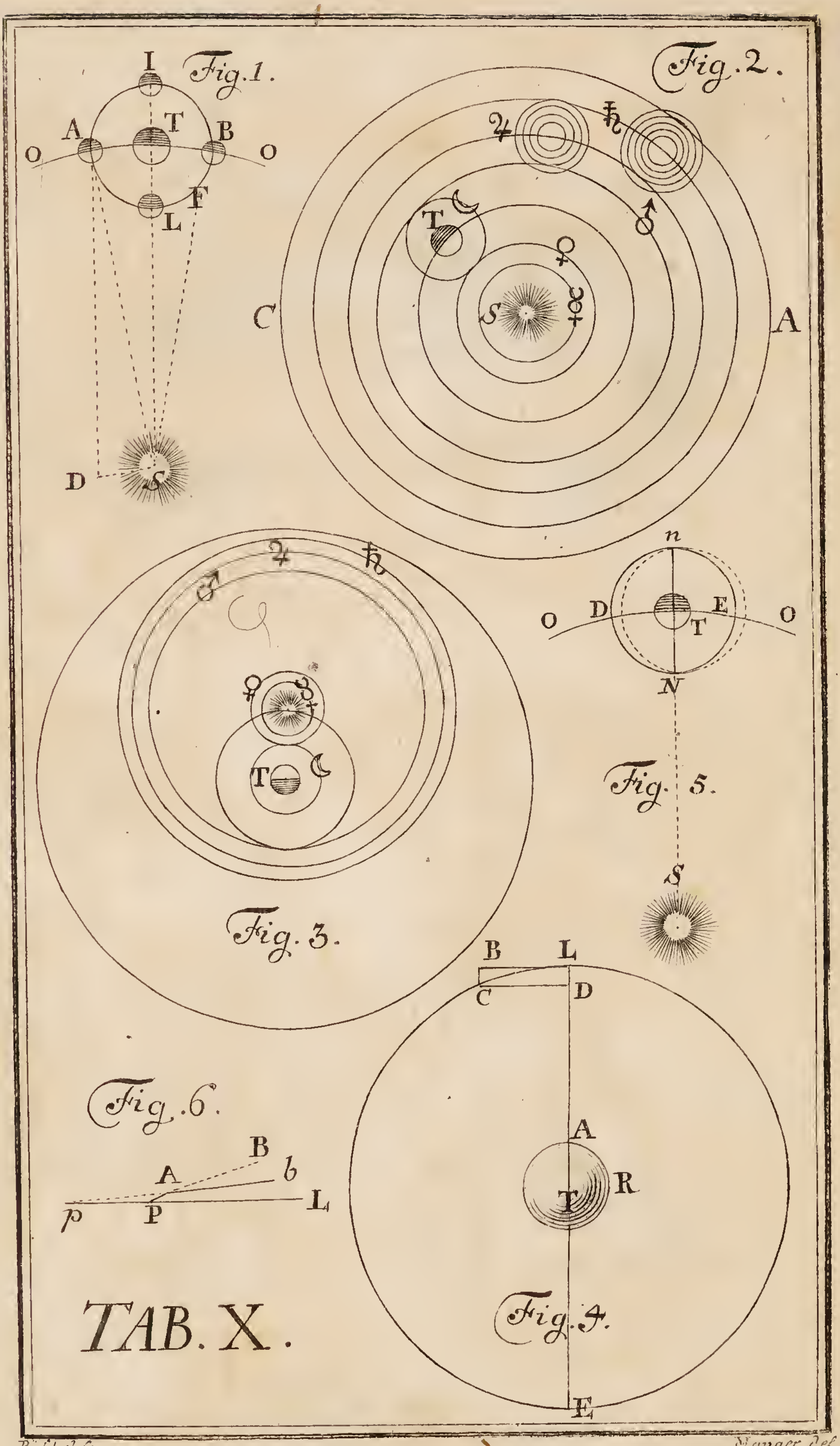
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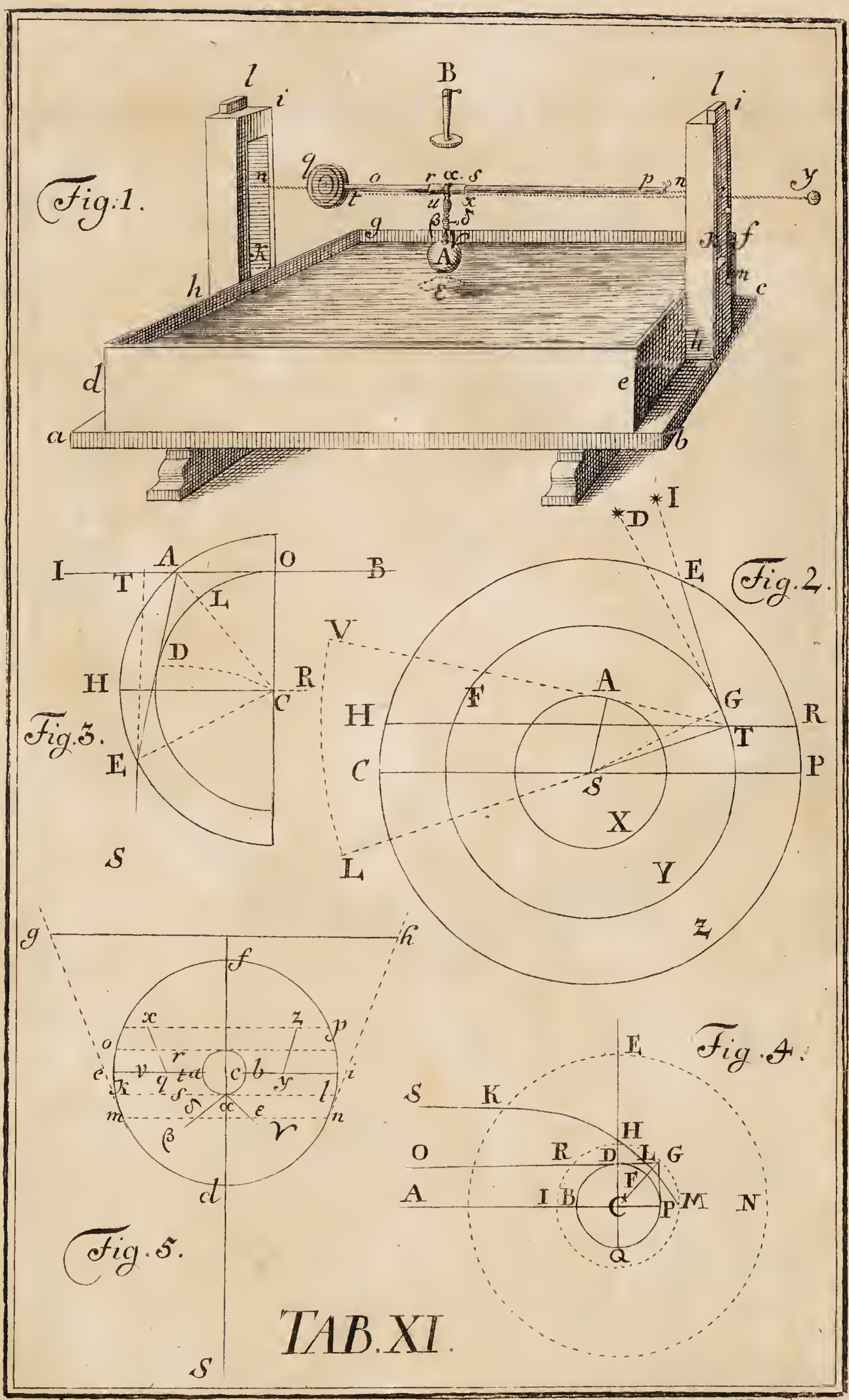

Fig. 1.
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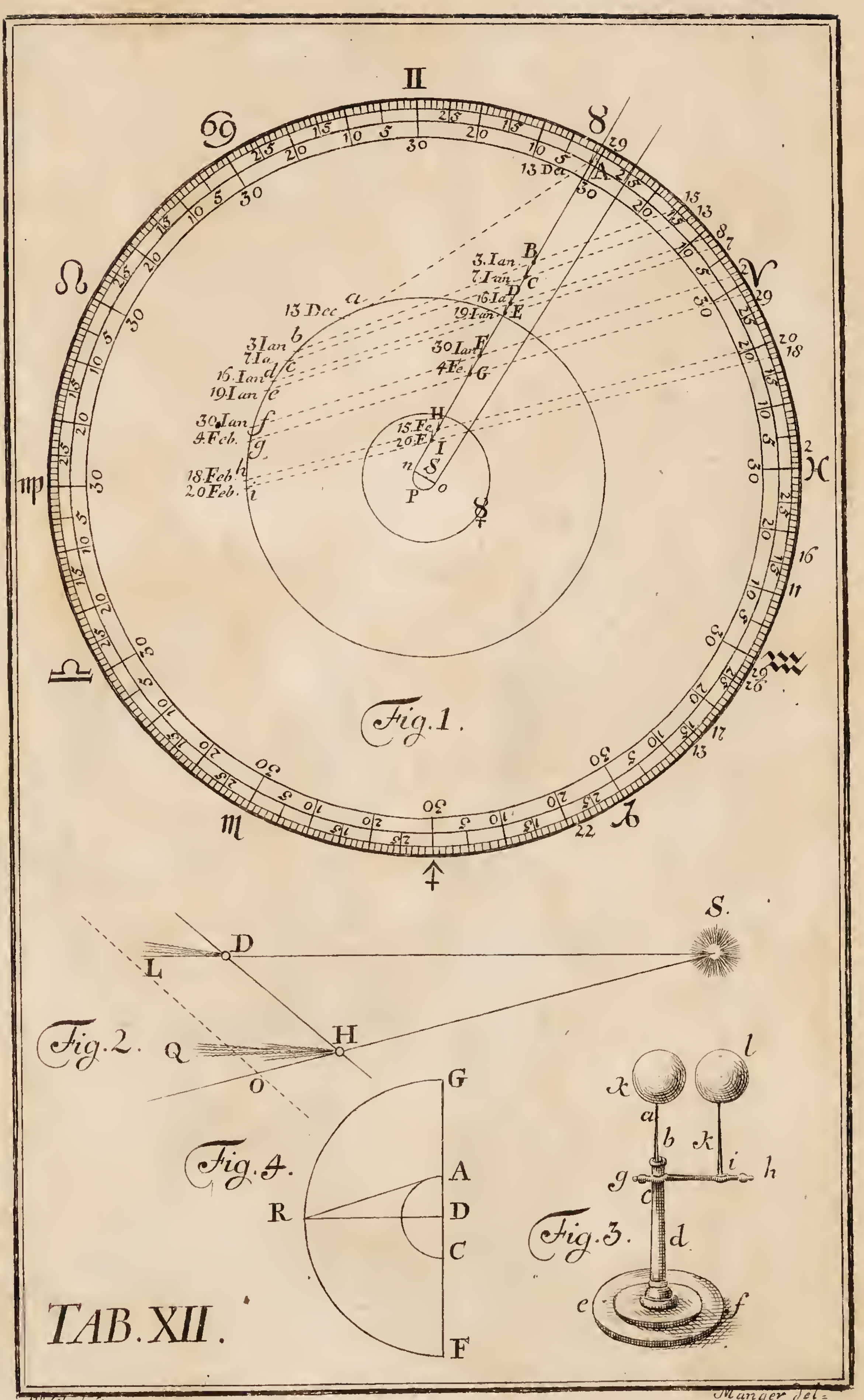
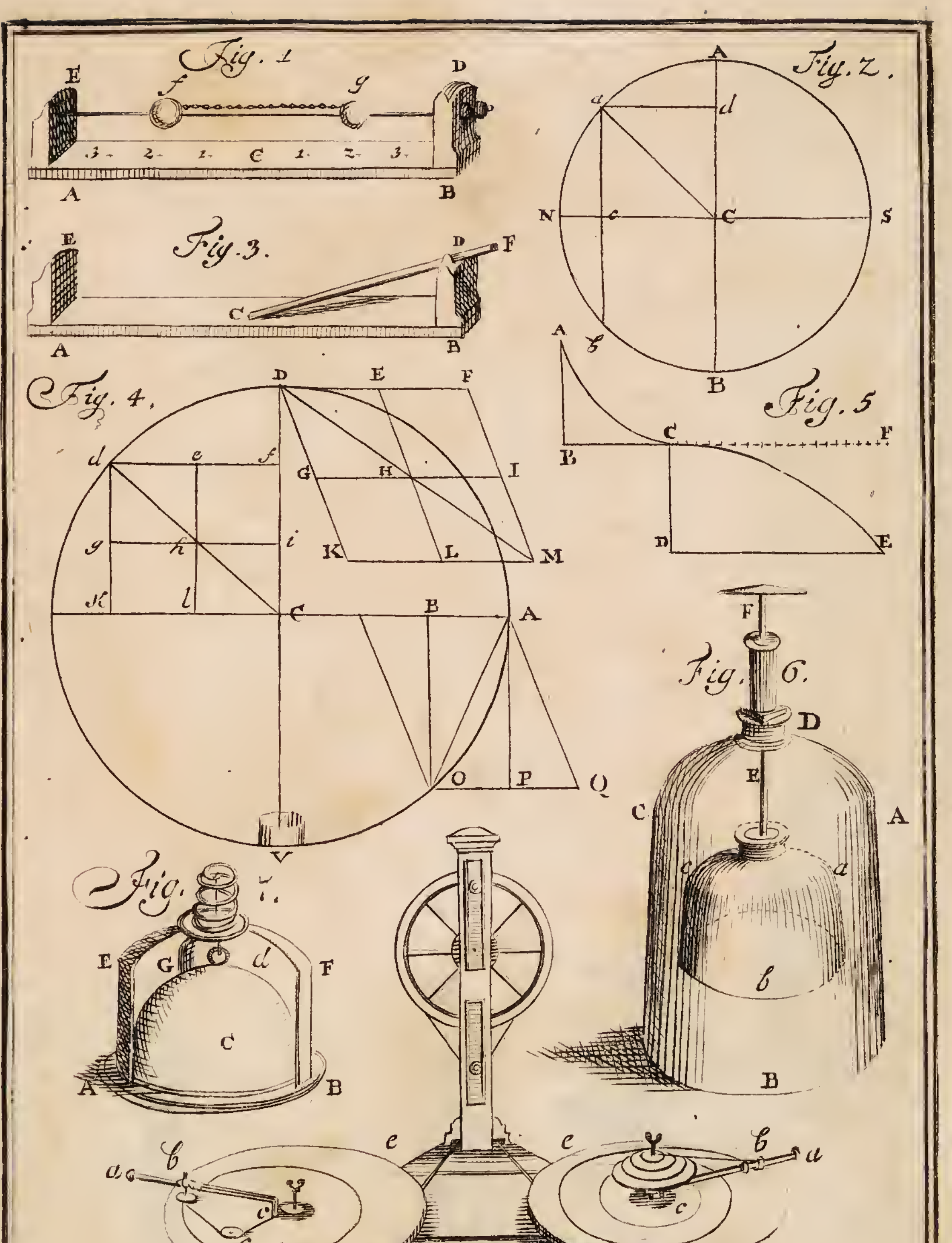
P: fc. M: d.



Püschel sc. Manger del.



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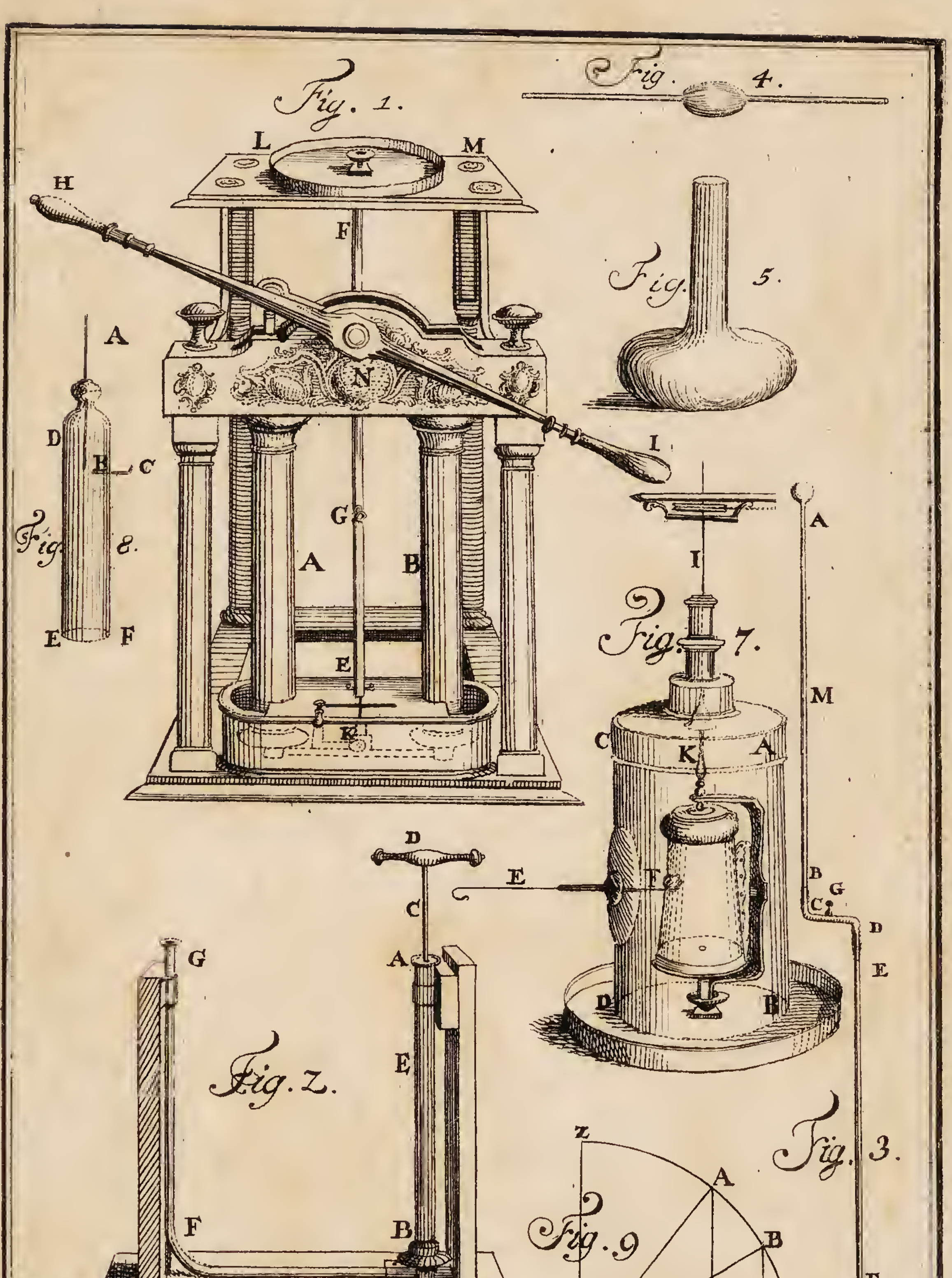

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